THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Towards a theory of natural occupation

Developing theoretical, methodological and empirical support for the relation between plot systems and urban processes

Evgeniya Bobkova

Department of Architecture and Civil Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2019

Towards a theory of natural occupation
Developing theoretical, methodological and empirical support
for the relation between plot systems and urban processes

EVGENIYA BOBKOVA

ISBN: 978-91-7905-196-9

Doctoral Dissertation Chalmers University of Technology
Doktorsavhandlingar vid Chalmers Tekniska Högskola
Ny serie Nr 4663
ISSN: 0346-718X

Department of Architecture and Civil Engineering
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone +46 (0)31-772 1000

Chalmers Reproservice
Gothenburg, Sweden 2019

Figures are original, by the author, unless otherwise noted

Abstract

Towards a theory of natural occupation

Developing theoretical, methodological and empirical support
for the relation between plot systems and urban processes

Evgeniya Bobkova

Department of Architecture and Civil Engineering, Chalmers University of Technology

Plot systems (or 'plots', 'lots', 'parcels', 'land divisions') is a commonly recognised structural component of urban form along with streets and buildings. They play a critical role in understanding urban processes in cities, not least of all because they link directly between the physical world and institutions, such as property rights.

The role of plots and plot systems in urban processes is addressed in this thesis as the theory of natural occupation. The theory argues that the structure of plot systems is the driver of a process of economic concentration and diversification of economic activity in cities, as described in the burgage cycle concept (temporal evolution of built form) and the spatial capacity concept (link between plot shape and urban diversity).

However, plot systems remain the least studied component of urban form, which this thesis contributes to on two levels. Firstly, by developing more precise quantitative descriptions of plots and plot systems by way of morphological measures and plot types. Secondly, by making use of these descriptions and empirically testing some central ideas in urban morphology, such as urban diversity. The thesis thus contributes to methodological and theoretical development in the field of urban morphology. However, it also demonstrates how these ideas on urban morphology can be a central contribution to theories in other fields addressing urban processes, such as urban planning and especially urban economics.

The research design of the thesis involves the development of a generic method to spatially represent plot systems, the identification of three key morphological variables of plots based on extensive literature review in the field of urban morphology, the development of analytical plot types using statistical methods of data-driven classifications and finally, empirical testing of the theory of natural occupation (by correlating the morphological variables and plot types with the concentration and diversification of economic activity in five European cities).

The empirical studies provide support for a direct relation between the shape and structure of plot systems and economic processes in cities and are an important contribution to urban design and planning practice.

Keywords: plot systems, urban-morphology, natural occupation, temporal evolution of built form, urban diversity, quantitative descriptions, morphological measures, types, statistical analysis

Acknowledgments

This page is one of the most important parts of my dissertation, which would not be completed without the help and support of my supervisors, colleagues and my family, who are mentioned below.

First of all, I would like to express my sincere gratitude to my supervisors Lars Marcus, Meta Berghauser Pont and Ioanna Stavroulaki for being an inspiration for me and as well as being challenging and demanding, for all the support they gave to me during my work on the thesis which is impossible to overestimate.

Many thanks to Meta Berghauser Pont, whose work I admired long before I started my Ph.D., without whom I would never know about Spatial Morphology Group at Chalmers, and who introduced me to the magic world of urbanism by numbers.

I am very grateful to Lars Marcus for his visionary perspective on urbanism, deep insights and discussions on theory, and giving me intensive support from the beginning until the very end of the study.

Thanks to Ioanna Stavroulaki, for her day-by-day help with my ups and downs, always giving fresh look when I many times was lost in-between multiple paths of my Ph.D.

Miguel Serra was there for me with his extensive feedback on the whole storyline of my thesis, especially on the methodology of research. Inspiring discussions with him helped me to bring my work to the next level on the final line of the Ph.D. study, which I appreciate very much.

Thanks to David Bolin – for his valuable advice on spatial statistics including cluster analysis and empirical investigations: his contributions helped me to advance the quantitative aspect of my Ph.D. study, but also opened me new horizons for a possible interesting extension of this study in the future.

Special thanks go to Ehsan Abshirini for his help in GIS data manipulation, to Jesper Olsson who gave me a hand with statistics at the earlier stage of this study, and to Jorge Gil for insightful feedback related to methodologies of data manipulation and cluster analysis.

I would also like to thank my examiner, Fredrik Nilsson, for his highly valuable feedback and discussions during yearly presentations.

Moreover, I would like to thank my opponent Anne Vernez Moudon and members of the doctoral committee Alice Vialard, Örjan Sjöberg, Abdellah Abarkan and Paula Femenias for their consent to be the part of my defence and for their feedback on this thesis.

It is important to emphasize how much I appreciate the help of my colleagues - Kailun Sun and Zuzanna Komorowska for assistance in delivering some of the maps and calculations for this research.

Many thanks to my other Chalmers colleagues Jorge Gil, Axel Heyman, Daniel Koch, Kailun Sun, Job van Eldijk, Alexander Hellervik, Leonard Nilsson, Anna Maria Orru, Elke Miedema and Kengo Skorick for inspiring tea talks and corridor discussions on space and architecture. I would also like to thank my administrators Anna-Johanna Klasander and Julia Fredriksson, and student advisor Krystyna Pietrzyk for the help with administrative issues and creating good work environment.

Further, I would like to mention my former Delft colleagues – Luis Carvalho and Birgit Hausleitner and express my gratitude for providing me with the opportunity to present the ongoing work on my Ph.D. study at TU Delft.

Finally, I would love to thank my family for being thousands of kilometres away but still sending their love and support, and my partner and friends for being here for me in this important moment in my life.

List of Papers and other Publications

This thesis consists of an extended summary and the following appended papers:

Scientific Journal Publications

Paper 3 Bobkova, E., Berghauser Pont, M. & Marcus, L., (2019a). Towards analytical typologies of plot systems: quantitative profile of five European cities. Environment and Planning B 0 (0), 1-17. https://doi.org/10.1177/2399808319880902

Paper 4 Bobkova, E., Marcus, L., Berghauser Pont, M., Stavroulaki, I., Bolin, D., (2019b). Structure of Plot Systems and Economic Activity in Cities: Linking Plot Types to Retail and Food Services in London, Amsterdam and Stockholm. Urban Science 3, 66. https://doi.org/10.3390/urbansci3030066.

Peer-reviewed Conference Papers

Paper 1 Bobkova, E., Marcus, L. & Berghauser Pont, M., (2017a). Multivariable measures of plot systems: describing the potential link between urban diversity and spatial form based on the spatial capacity concept. Lisbon, the Proceedings of the 11th Space Syntax Symposium, pp. 47:1-47:22.

Paper 2 Bobkova, E., Marcus, L. & Berghauser Pont, M., (2017b). Plot systems and property rights: morphological, juridical and economic aspects. Valencia, XXIV International Seminar of Urban Form.

Paper 5 Marcus, L., Bobkova, E., (2019). Spatial configuration of plot systems and urban diversity: empirical support for a differentiation variable in spatial morphology. Beijing, The Proceedings of the 12th Space Syntax Symposium.

Table of Contents

PART TWO PUBLICATIONS

Part I

Extended summary

When the boundaries are real enough
to be violated, the plot exists.

Why is the plot the problem child in urban morphology? /…/
For subjective observation to be useful it must be converted into
objective information – accurate, measured, and recorded.
So it is for the plot.

(Scheer, 2018)

A concept such as property is meaningless
if divorced from spatial practices and representations

(Blomley, 1997)

Section 1

Introduction

1. 1 Importance of plot systems for urban processes in cities

A land plot (also 'lot', 'parcel' or 'land division') is a piece of land bound by legally defined borders that constitutes a basic unit of land control and use. Repetitions of land plots in cities form plot systems, that are, at first sight, invisible to the naked eye simply because they are immaterial. At the same time, these plot systems play a critical role in urban planning and design of cities, since they directly or indirectly connect their physical structure (like buildings) to institutions, such as property rights, land uses, zoning codes or the like. In other words, socio-economic use and performance of cities plus, in some countries, their visible aspects such as the form and height of buildings, are often simply a manifestation of the hidden order imposed by the layer of plot systems. This, in turn, means that this layer (often overlooked by planners and architects) is central to the large variety of urban processes in cities and particularly to our understanding of the relationship between these processes and physical form of cities.

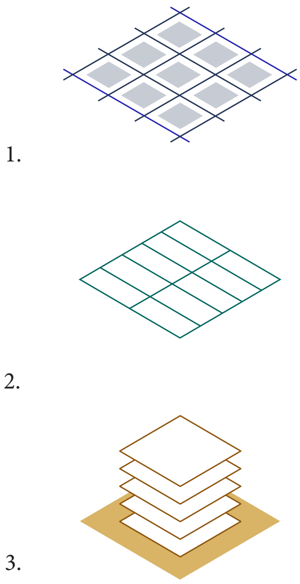


FIG. 1.1 Three structural components of urban form: streets (1), plots (2) and buildings (3)

It is crucial for architects and other practitioners involved in urban development projects to have a good understanding of this relationship, because plots and plot systems are things they can influence directly (and thus indirectly guide urban processes too). In urban morphology, plots are recognised as one of the three structural components of urban form, along with streets and buildings (Figure 1.1) (Kropf, 1996, 2017; Moudon, 1997, 1994; Scheer, 2018, 2016; J. W. R. Whitehand, 2001). In studies, this has been linked to particular socio-economic processes in cities, such as the temporal evolution of built form (Conzen, 1960; Moudon, 1986) and urban diversity (Marcus, 2010, 2000). Even so, plot systems remain the less studied of these components (Scheer, 2018). This thesis aims to remedy that, firstly by identifying and formalising essential morphological properties that help us describe and analyse plot systems and, secondly, by theoretically and empirically linking plot systems to urban processes.

The wider aim of the thesis is to demonstrate how such morphological descriptions and analysis may also support theory in other disciplines addressing urban development. For this, the thesis makes particular use of the institutional theory of urban planning presented by Webster and Lai (2003), in which property rights (and by extension plot systems) play a central role. They point out that historically, cities grow and develop following processes of increased division of labour made possible by the typical proximity between people in cities, which allows exchange and economic activity to become gradually more specialised and diversified. In institutional terms, they argue, this process is aligned with an increased subdivision of property rights, which also demands a further division of land into more plots. While Webster and Lai take a primarily institutional view of the process of urban evolution, there is a link here to the ideas on urban morphology mentioned above. Firstly, the notion that plot systems work as an organisational framework for the temporal evolution of built form as described by such scholars as Conzen (1960). And secondly, the hypothesis that the increased subdivision of property rights to land through plot division is vital to a process of urban diversification (Marcus, 2010, 2000).

Hence, this thesis aims to contribute to the understanding of plots and plot systems on several levels. Firstly, by developing more precise descriptions of plots and plot systems, this thesis is a methodological contribution to urban morphology. Secondly, by using these descriptions in empirical tests of some central ideas in urban morphology (more precisely, the hypothesis that plot systems are central to the concentration and diversification of economic activity in cities), it also makes a theoretical contribution to the field. Thirdly, by demonstrating how these ideas on urban morphology can make a central contribution to theories in other fields addressing urban processes, for example, in urban planning and urban economics, as examined by the institutional theory on urban development presented by Webster and Lai (2003). Accordingly, this thesis also constitutes a theoretical and methodological contribution to these fields.

Central to this thesis are the parallel ideas, firstly, that urban development and growth is aligned with a process of economic diversification, which we find argued in any urban economics textbook (like O'Sullivan, 2019) and secondly, that this is supported by a greater differentiation of property rights, which we find argued in planning theory (including Webster and Lai, 2003). This second point, in turn, is supported by a greater subdivision of urban land into plots, as argued in urban morphology (including Marcus, 2000) and to which this thesis makes a specific contribution.

The role of plots and plot systems in this process has been addressed previously as the theory of natural occupation (Marcus, 2001), formulated in parallel with the theory of natural movement[1] (Hillier et al., 1993), central to Space Syntax research (Hillier and Hanson, 1984), a configurational approach to urban morphology. The background is what Hillier (1996) has identified as generic functions of urban space, movement and occupation, with movement primarily taking place in the street network of cities while (long-term) occupation takes place in urban street-blocks and is typically supported by buildings. Many studies have demonstrated how natural movement[2] is largely distributed by the configuration of the street network (cf. Hillier et al. 1993; Hillier and Iida, 2005). In congruence with this, Marcus (2001) has argued that the differentiation of urban street-blocks into plots similarly supports the diversification of long-term occupation in cities[3].

We hence propose that, just as the street network configuration is argued to be the main driver of pedestrian movement (Hillier et al, 1993, Hillier, 1996), so the structure of plot systems plus the building layer may be the driver of more intense and diverse use of occupational space. This is described in the burgage cycle concept (Conzen, 1960) and spatial capacity concept (Marcus, 2010), with both aspects combined in the theory of natural occupation (See Section 2).

1. The theory of natural movement refers to the dependency between three attributes: street network configuration, pedestrian movement and urban attractions (such as different land uses and density), with street network configuration argued to be the main driver of the other two factors (Hillier et al., 1993).

2. 'Natural movement' here means movement, not driven by any particular "attractors or magnets" (Hillier et al., 1993). In other words, it is potential movement from everywhere to everywhere. In space syntax theory, the argument is that this captures the logic of movement in cities better than the more established origin-destination way of thinking.

3. 'Natural occupation', here means long-term occupation; not driven by particular "briefs or regulations" (Marcus, 2001), but by the division of land itself (this will be expanded upon in Section 2.3).

1. 2 **Problem definition**

As described above, a range of theories in urban economics, urban planning and urban morphology highlight the importance of plots (such as Conzen, 1960; Marcus, 2001; Webster and Lai, 2003). However, due to the lack of generally accepted theories and techniques for describing and analysing the morphology of plot systems, little empirical research so far supports these theories (Scheer, 2018). This is partly because plots bridge many academic disciplines, including private property law, geography, economy and planning, real estate development, urban morphology and architecture; each using their own jargon and set of definitions.

A central dissonance here is that plot systems are simultaneously a) legal entities designating property rights and, indirectly, land use regulations and b) geographical entities delimiting pieces of land (Kropf, 2019, 2018, 1997). Further, in Scheer's interpretation of Kropf (2018), the central reason for the ambiguity of the term is that it presupposes a relationship between spatial form and human behaviour (Scheer, 2018).

From the perspective of urban morphology, this raises methodological problems. If we want to study the relation between urban form and urban processes of any kind (such as economic diversification), we need to separate form and function and find a means of consistently describing each in isolation. In other words, if the aim is to understand what the plot as a morphological entity 'does', and test or validate a number of theories stating that, in this respect, plots are important factors in, say, the typical diversification we find in cities, then we need to define and describe the plot in a manner relevant to these purposes. It is therefore proposed that we should isolate the morphological or spatial dimensions of the term 'plot' from its legal or institutional dimensions and develop quantitative descriptions of its form that are relevant to urban diversification. Only then can we test what the plot, as a morphological entity, does and how it is related to urban processes. In the case of this thesis, this is the concentration and diversification of economic activity in cities over time.

1. 3 Thesis purposes and delimitations

The description of plots and plot systems suggested here lies within the broad field of urban morphology, which consists of many sub-schools and approaches (Gauthier and Gilliland, 2006; Kropf, 2009; Moudon, 1992; Oliveira, 2016; Scheer, 2016). Following Scheer (2016), we see urban morphology as a distinct field of knowledge that does not aim to develop a description and understanding of all the complex processes we find in cities. According to Scheer, urban morphologists are concerned with defining and conceptualising a particular segment of knowledge about cities, that is the physical form of cities and, in turn, investigating how that physical form is related to other urban processes (ibid.). That does not mean this thesis claims that physical form determines urban processes or vice versa. However, it does mean that we understand physical form to create conditions that generate more or less probable outcomes in such processes. In other words, we argue that there is a probabilistic relation between the two.

In the case of this particular thesis, the above means that we want to demonstrate a relation between the morphological shape and structure of plot systems and the processes of economic specialisation or diversification typically found in cities. Moreover, to test that we need to develop rigorous descriptions of plots systems that mean we can quantify their form and correlate them to urban processes consistently and precisely.

The overarching purpose of this thesis is to develop a consistent framework for what we call 'the theory of natural occupation', in which a central part of the long-term evolution of cities is understood to be a process of economic concentration and diversification supported by an ever-finer subdivision of property rights to land and reflected in more fine-grained plot systems (Webster and Lai, 2003). This framework includes theoretical discussions about the importance of plot systems in various fields that study cities (Bobkova et al., 2017a, 2017b), as well as methodological (Bobkova et al., 2017a, 2019a) and empirical contributions (Bobkova et al., 2019b; Marcus and Bobkova, 2019).

The specific objective of this thesis is to develop rigorous quantitative descriptions of the morphology of plot systems, as both measures and typologies, and to use these to test the existence of a relation between plot systems and, first, the concentration of economic activity in cities and, second, the diversity of these activity.

It is important to underline that this thesis is limited to the study of the morphological dimension of plot systems and does not take into consideration such things as the impact of land-use regulations (as further discussed in Papers 1 and 4). It is fully recognised that such regulations are vital to the performance of plots and plot systems in this regard and operate as central instruments in urban planning. However, they are not the focus of this thesis.

Another delimitation of this thesis is that the study of temporal transformations of the urban fabric is beyond the thesis' scope. Though such study would be a very interesting undertaking, it would require longitudinal data on plot systems. This kind of data (historical ownership patterns or property maps) is normally hard to collect, especially for complete city regions.

1. 4 **Research question and propositions**

The general research question of the thesis is as follows:

- ***Main RQ.*** *How do we quantitatively describe morphological aspects of plots and plot systems so that we can empirically test existing theories of urban morphology, urban planning and urban economics (which argue that the shape and structure of plot systems influence economic processes in cities, especially the spatial distribution and degree of diversification of economic activity in cities)?*

This research question is broken down into a set of operational research questions that guide the structure of the thesis and provide the narrative for the five published papers (see Part II, Publications).

RQ 1

Paper 1
(Bobkova et al., 2017a)

- ***RQ1. The concept of plots in urban morphology.*** *What is the role of plots in morphological theories and what are the essential morphological variables that enable us to better test such theories? This question is addressed in Paper 1 (Bobkova et al., 2017a).*

Proposition 1: There is no systematic development of quantitative descriptions of plot systems in urban morphology, let alone any congruent framework for them, even though plot systems play a central role in many fields and disciplines (some of them outside urban morphology and urban design).

Scientific task: To develop such descriptions in the form of quantitative morphological measures of plots within a congruent framework and based on central theories about plot systems found in urban morphology (Paper 1).

RQ 2

Paper 2
(Bobkova et al., 2017b)

- ***RQ2. Importance of plots in related fields.*** *What other important aspects of plots (not considered in urban morphology) do we need to consider when developing quantitative description of plots and plot systems? RQ2 is addressed in Paper 2 (Bobkova et al., 2017b).*

Proposition 2: Plots and plot systems, with their inherent duality of being both morphological and institutional entities, have an unusual degree of relation with other academic fields.

Scientific task: To conduct a review of literature in other disciplines addressing plots and plot systems, with the aim of positioning and supporting the need for quantitative description of plots and plot systems (Paper 2).

RQ 3

Paper1 + Paper 3
(Bobkova et al., 2017b; 2019a)

- ***RQ3. Methodological contribution.*** *Are there any generic morphological regularities in plots, that enable us to describe and classify them precisely and repeatably? This issue is first addressed in Paper 1 (Bobkova et al., 2017a), where quantitative measures of plots and plot systems are introduced. It is then extended in Paper*

3 (Bobkova et al., 2019a) in which typologies of plots and plot systems are analytically generated.

Proposition 3: Typologies are commonly used in both urban morphology and urban design practice, but are generally based on visual assessment, which may be adequate for broad description. However, for analytical purposes concerning the performance of urban form, there is a need to develop quantitative descriptions that can be applied to large datasets and replicated in different contexts. Recent approaches in quantitative urban morphology increasingly employ data-driven classification methods that allow for the study of large datasets and the classification of urban form in all its variety. Hence, it may be very important to adopt methods which enable us to develop plot types algorithmically.

Scientific task: To develop a method to generate generic descriptive and reproducible plot types that could be used to compare the similarities and differences of plot systems across various urban landscapes.

RQ 4

Paper 4 + Paper 5
(Bobkova et al., 2019b; Marcus and Bobkova, 2019)

- ***RQ4. Testing theory.*** *To what extent do the shape and structure of plots contribute to economic diversity in cities? This research question is split into two parts, where we first associate plot shape and structure with the number of economic activities in cities, Paper 4 (Bobkova et al., 2019b) and then with their diversity, Paper 5 (Marcus and Bobkova, 2019).*

Proposition 4: The process of economic diversification, typical of cities, is generally aligned with a process of land subdivision into plots of smaller size, more regular shape and smaller street frontage.

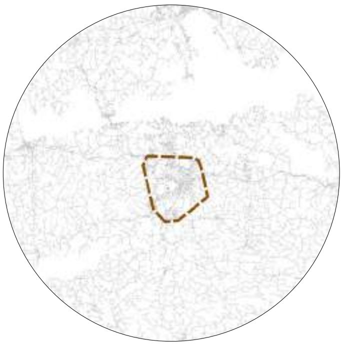
Scientific task: To test whether higher concentration (Paper 4) and diversity (Paper 5) of economic activity do indeed correlate with the morphology of plot systems. This is not to prove the deterministic correlation between the shape of plots and economic performance, but to demonstrate how the morphology of plot systems creates conditions that increase the probability of a higher concentration or diversity of economic activity.

1. 5 **Study areas of investigation**

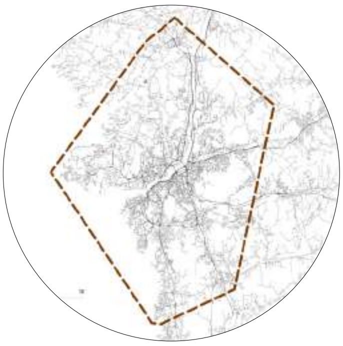
Though the thesis aims to develop comprehensive quantitative descriptions of plot systems, its geographical scope is limited to the European context. It therefore covers five European cities that serve as a testbed for our investigation: London, Amsterdam, Stockholm, Gothenburg and Eskilstuna[4]. The reasons for choosing these five cities are as follows. London, Amsterdam and Stockholm are capital cities with certain socio-economic and historical similarities, but which also vary in their regional structures and planning traditions. Stockholm represents the highly planned city with a dispersed finger structure, intertwined with green and blue wedges; London represents the less planned city, that has grown incrementally from its centre and absorbed nearby villages; and Amsterdam represents a city in a dispersed semi-planned poly-centric conurbation (Randstad) (Berghauser Pont et al., 2019).

In Sweden, two additional cities (Gothenburg and Eskilstuna) were added because they have been developed within the same institutional planning tradition as Stockholm, but differ in size: Stockholm has 381,878 plots, Gothenburg has 303,835 and Eskilstuna has 94,731 plots (one third the size of Gothenburg, see the Atlas of Plots). The proposed selection of cities allows cross-

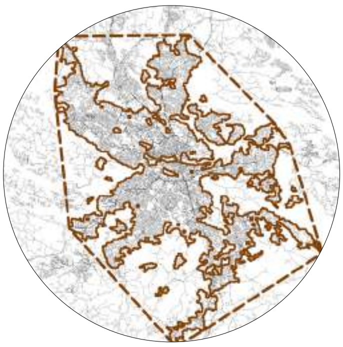
4. For the methodology used to define the exact study areas and process plot systems data, see Section 5 as well as the Atlas of Plots.



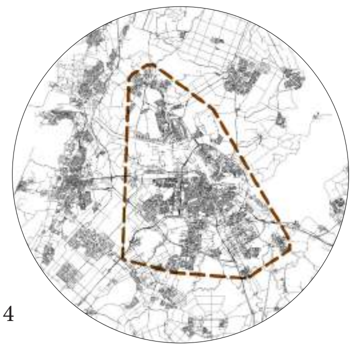
1



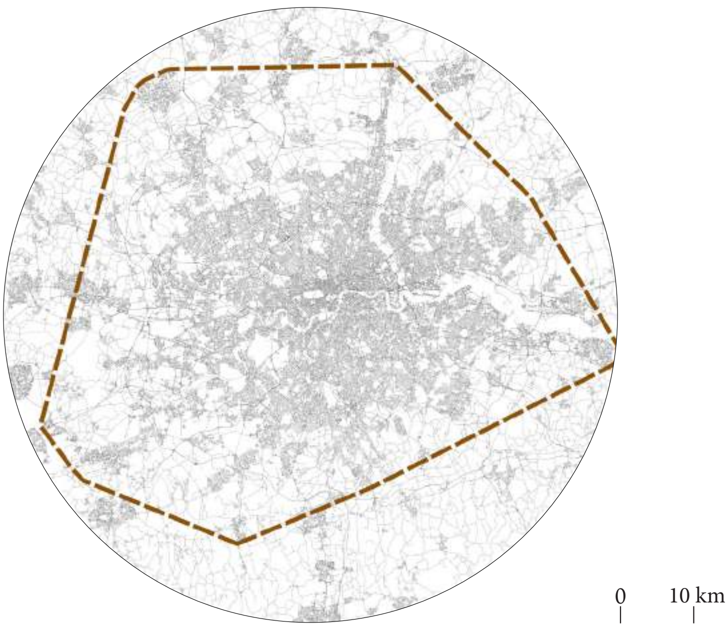
2



3



4



5

FIG. 1.2 Overview of the study areas. 1.Eskilstuna; 2. Gothenburg; 3. Stockholm; 4. Amsterdam; 5. London

European comparisons, with the comparison cities varying in their planning traditions. It also allows us to study the effect of city size within one and the same planning tradition.

1. 6 **Extended summary overview**

In the next section (Theory of natural occupation), the role of plots will be positioned within a broader field of theory about urban development; connecting the role of plot systems in urban morphology with institutional theories of urban development.

Section 3 introduces the broader methodological framework, including how the thesis is positioned within the field of urban morphology. It highlights the central methodological approaches used in the thesis: quantitative and typological descriptions in urban morphology.

Section 4 presents existing concepts that relate plot systems to various urban processes. There is also an overview of existing quantitative measures and plot types, identifying the knowledge gaps in this area and the need for more stringent typologies or classifications of plots to be developed.

Section 5 presents the research design of the thesis. The methodological steps of the study are described in detail, covering such technical issues as data collection and editing, developing spatial measures of plots, classifying plots into typologies and, finally, empirical validation (via statistical analysis) of the theories that have been introduced.

Section 6, with the Atlas of Plots, presents the results of the study, including the quantitative descriptions of plots and the results of the empirical tests.

The last Section (Discussion) presents reflections on the particular contributions of the thesis. This includes research into cities and their development, practice in urban planning and design and an outline of possible future research directions.

The thesis concludes by presenting a summary of all five papers.

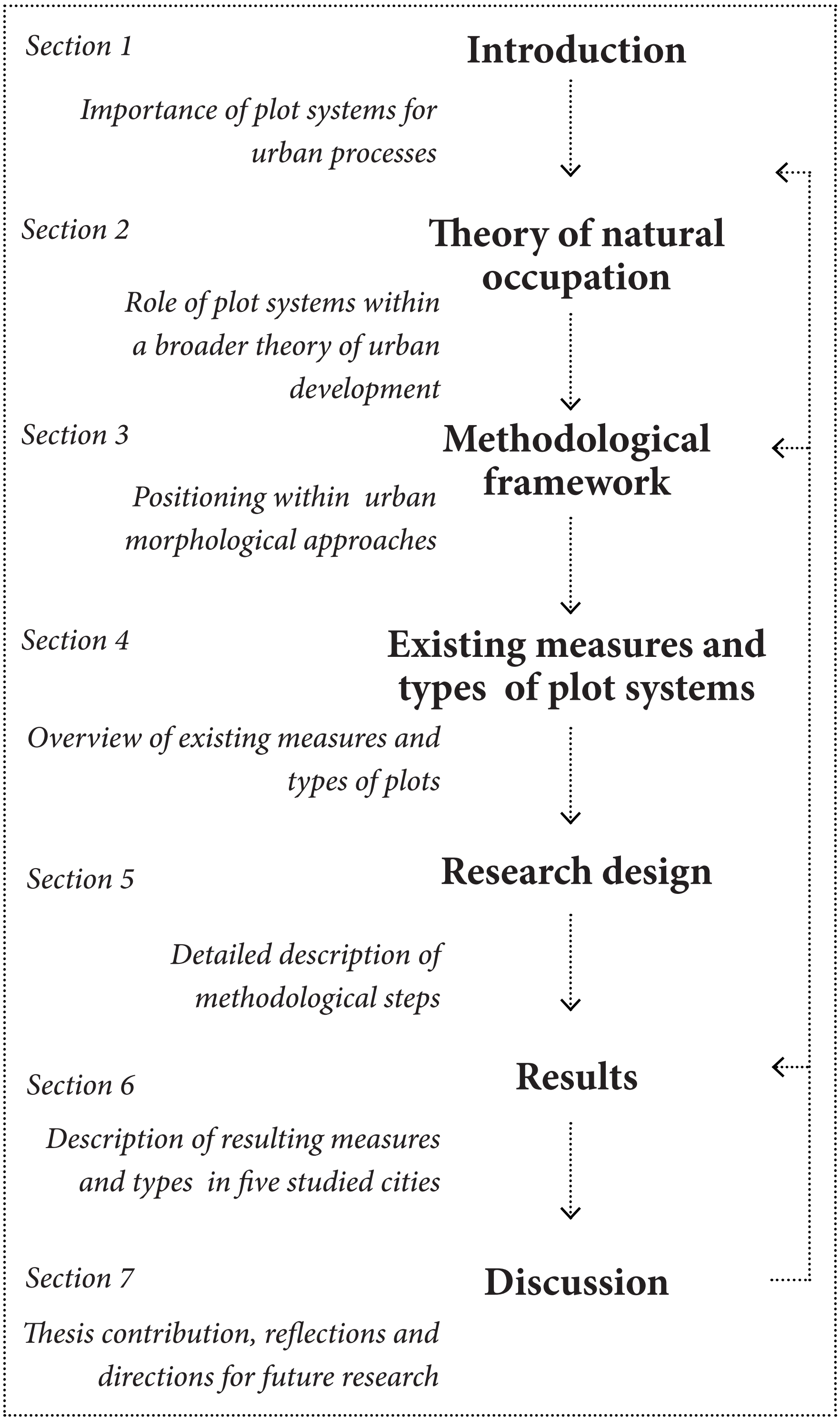


FIG. 1.3 Extended summary overview

Section 2

Theory of natural occupation

2. 1 **Framing property rights concept**

In legal terms, a land plot may be referred to as a unit of control, primarily corresponding to ownership but often also used to delimit land use regulations (Kropf, 2019, 2018, 1997).

Ownership always involves some entity which may be referred to as 'property'; private property, for instance. However, the term 'property' is also specifically used to denote land as an owned entity, which may lead to some confusion. By extension, the term 'property rights' may also refer to any owned entity and regulates how a property may be owned and used. This thesis treats both 'property' and 'property rights' as referring to land. As described in Paper 2, the concept of 'property rights' is primarily used here as understood within the framework of legal geography, in which the primary property right is understood as the right to exclude (Blomley, 1997). Blomley (ibid.) points out that the critical characteristic of land property is not the relationship between owner and owned, as presupposed in the classical view of property rights theory (Alchian and Demsetz, 1973); rather, it is the relationship between the owner and other owners (Babie, 2013; Blomley, 1997; Merill, 1998).

Land as property also presents some challenges when it comes to defining the property itself. Many things that can be owned almost define themselves, such as chairs or tables, even though the property rights connected to them can be complicated. However, land is not a series of easily separated things and, furthermore, cannot be moved. This is where the practice of land division comes in. According to Barthes, as cited by Blomley (1997), "ownership depends on a certain dividing of things: to appropriate is to fragment the world, to divide it into finite objects subject to man in proportion to their very discontinuity; for we cannot separate without finally naming and classifying and, at that very

FIG. 2.1 (on the left) Movie scene from "Dogville" illustrating spatial dimension of property rights moment, property is born". Following Bromley's interpretation of the property rights concept, Lai and Davies (2017) point out that systematic internal partitioning of land into units called 'lots', 'plots' or 'parcels' is paramount for spatial arrangements in cities (Lai et al., 2018; Lai and Davies, 2017).

This idea may be explicitly illustrated by the movie Dogville (see Figure 2.1), in which simple divisions drawn on the ground demarcate exclusivity of different, privately controlled, spaces.

The internal partitioning of land into plots is generally administrated in a land cadastre that registers such things as ownership, location, extension and value for each plot. Normally, this covers all sorts of land and not just plots for buildings, but those for streets and public spaces as well. Importantly, practices can vary greatly from country to country, depending on each country's legal system. This highlights the difficulty of uniformly describing plot systems[5]. The approach chosen in this thesis, following Hillier's notion of generic functions (1996), distinguishes plots for long-term occupation (primarily found within street blocks) from plots for movement and temporal occupation (primarily found in streets and public spaces).

5. For example, in UK, instead of cadastral system freehold and leasehold property systems are used, where the former, rather similar to land cadastre corresponds to ownership of land (Paasch, 2011)

In conclusion, we see how the very division of land into the separate pieces we call 'plots' (and which jointly make up plot systems) is there to allow land to be owned, to become property, whether privately, publicly or commonly owned. Further, this geographic division of land is connected to the legal frameworks called 'property rights', which more precisely regulates how different pieces of land can be owned and used. It is this inherent legal-geographic duality that makes plots and plot systems such a singular component in the field of urban morphology; and such an important component of our understanding of urban processes.

2. 2 **Spatial order of property rights in planning and legal geography**

A range of studies in legal geography and urban planning highlight the importance of the geographic dimension of property rights. However, as discussed in Paper 2 (Bobkova et al., 2017b), while legal geography scholars recognise the importance of the 'spatial turn' in legal thought and call for multi-disciplinary approaches that engage social sciences, history and political sciences (Braverman, et al., 2013), far less attention is paid to the morphological dimension, that is, the particular structure and shape of plots and plot systems. How land as property in urban development projects is typically subdivided into plot systems of a particular structure and shape (a task carried out by land surveyors, urban planners or architects) is often overlooked in this literature, as discussed in Paper 2 (Bobkova et al., 2017b).

When it comes to urban planning, as discussed in Paper 4 (Bobkova et al., 2019b), there are many studies (Chung, 1994; Gibb and Nygaard, 2006; Lai et al., 2018; Lai and Hung, 2008; Needham, 2006; Webster and Lai, 2003; Zhu et al., 2007) that take an institutional view of the practical task of "governing, administrating, managing and planning cities" (Webster and Lai, 2003, p. 1). These particular studies express great concern for property rights and, by extension, for plot systems (spatial dimension of property rights). Such studies often concern real estate and/or land redevelopment (Adams et al., 2013, 2002; Buitelaar, 2003; Buitelaar and Segeren, 2011; Chau et al., 2018; Love and Crawford, 2011; Souza et al., 2018; Zhu et al., 2007) or address the theme of cities as complex self-organising systems (Cozzolino, 2019; Moroni et al., 2019). However, most of these studies do not devote specific discussion to plot systems (the morphological dimension of property rights).

Property rights and, to some extent, plot systems are both explicitly addressed in Webster and Lai's work "Property rights, planning and markets" (2003), which makes it a useful reference for this thesis. From the standpoint of institutional economics, they argue, cities are fundamentally spontaneous or self-organising systems. They make the broad assumption that cities are driven by "constrained spontaneity" (ibid.), where spontaneity concerns distributed individual action (typically taking the form of markets) and constraints are imposed by formal and informal institutions. Webster and Lai's interpretation of property rights theory is that any commodity, including land, has multiple attributes that are, in principle, infinitely separable so that rights can be assigned to them (ibid.). Moreover, according to Webster and Lai, the degree to which such rights are assigned depends partly on the value of the attribute in itself and partly on the cost of assigning or maintaining such rights (ibid.). The latter includes the creation of legal frameworks and the administration and the policing of these, generally referred to as 'transaction costs'.

As discussed in Papers 2 and 4 (Bobkova et al., 2019b, 2017b), property rights theory, and specifically the way Webster and Lai frame it (2003), proves to be an essential tool for bridging the legal or institutional side of plots with their morphological side.

It is beyond our scope to engage in the debate about the property rights concept in legal geography and planning theory. However, we find it important to note that while the plot remains "the problem child" of urban morphology (Scheer, 2018), this spatial dimension of property rights has a vital role in a wide variety of research, which addresses cities from the standpoint of jurisprudence, economics and planning.

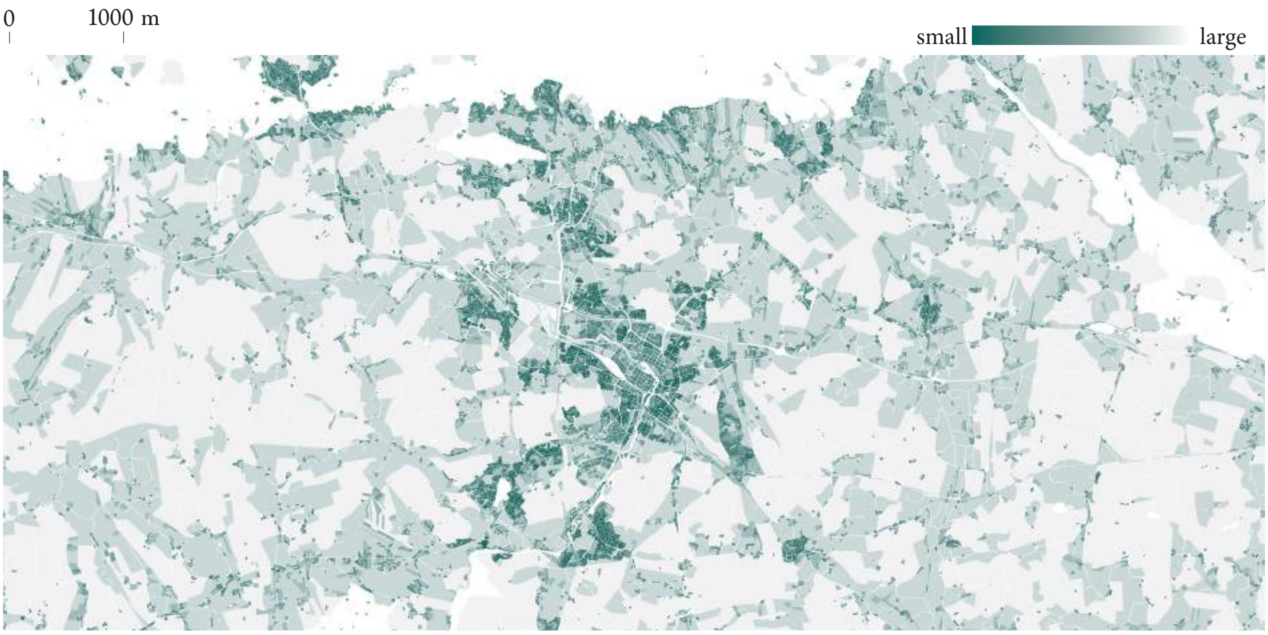
Thus, the aim of this thesis is to develop the means for coherent descriptions of the morphology of plots and plot systems. This allows us to demonstrate the importance of this entity in other fields of study; ones that address cities and their development. We will do this through the theory of natural occupation (Marcus, 2001), in which the morphological dimension of plot systems is argued to significantly influence both the temporal evolution and economic concentration and diversification of cities.

2. 3 **Bridging urban morphology and urban development concepts into the theory of natural occupation**

Webster and Lai (2003) base their theory on the common observation that cities are typically sites of economic specialisation, due to the proximity between people allowing extensive division of labour. They argue that this also leads to an extensive division of property rights, including division of land into more fine-grained plot systems and more regularly shaped plots. Hence, they understand the long-term process of urbanisation to be aligned with increasing subdivision of land and property rights. They point out that land plots which emerge in cities during the process of economic diversification are generally smaller in size and more regular in shape than rural land parcels (ibid.).

We thus observe a characteristic trend in cities towards greater subdivision of land as we near their centre (see, for example, the map of Eskilstuna plot sizes, Figure 2.2). More central locations have greater access to a larger number of people, which provides an opportunity for increased specialisation of economic activity. Therefore, these locations will face increased competition that will raise land values. This can outweigh the increased transaction costs of further separating property rights and often leads to a finer division of land. (Bobkova et al., 2019b).

FIG. 2.2 Illustrative map of plot sizes in Eskilstuna, Sweden, that clearly illustrates the greater subdivision of land from periphery towards the center.

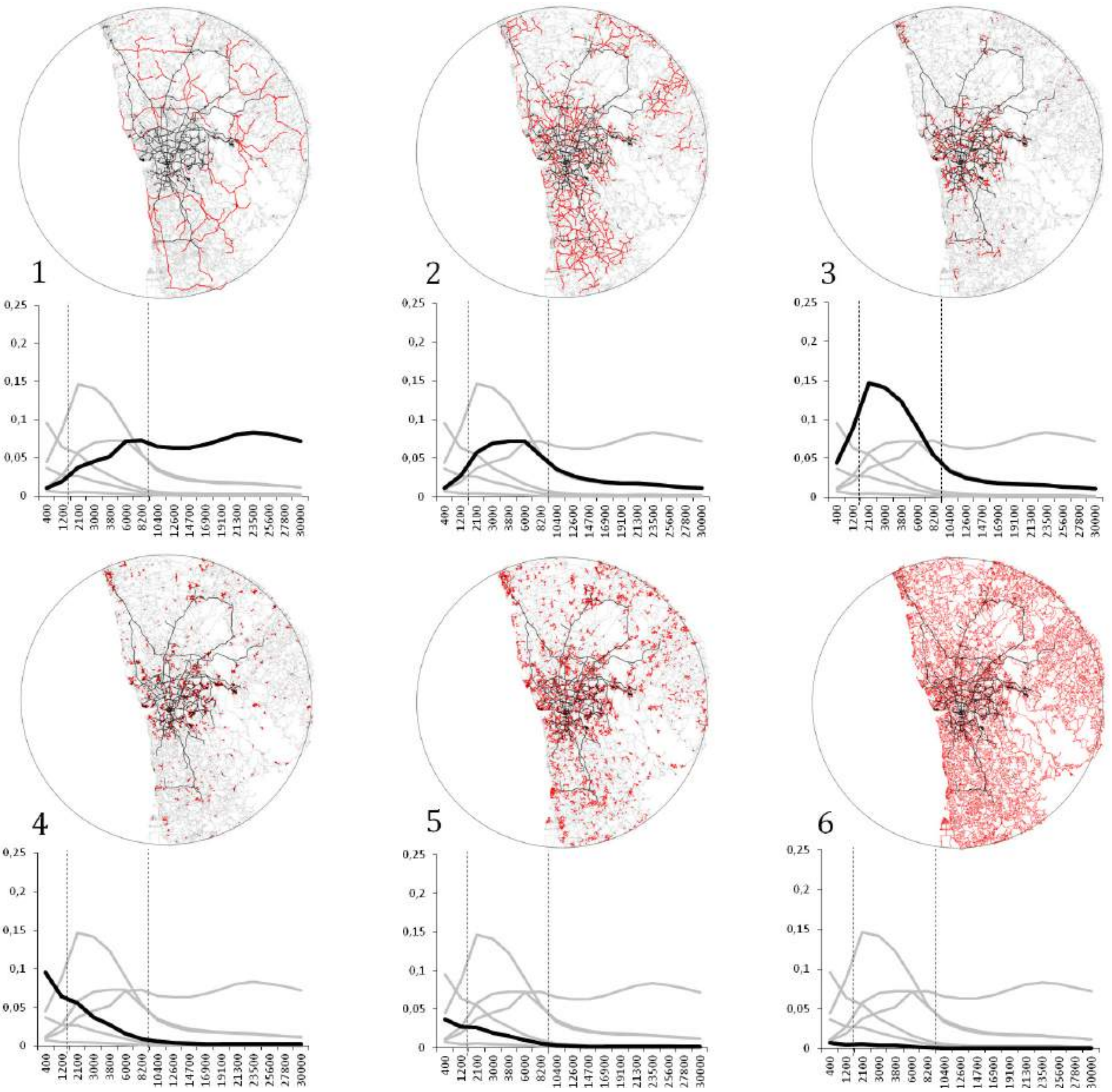


One may argue, that a counteractive tendency also can be observed. When cities continue to grow, plot systems in very central locations tend to shift towards a coarser land-division. This seems to happen when such central locations may be more efficiently managed by central administration, for instance as shopping malls, thereby avoiding the transaction costs of dealing with a long series of land contracts. The "plot system" (representing the delineation of property rights) then reappears in a new form, now as a structure of sublet floor space within the shopping mall, presenting cheaper transaction costs than land contracts (Bobkova et al., 2019b). Although interesting, this form of subdivision on another scale is not within the scope of this thesis.

The idea that the long-term growth of cities is aligned with a process of economic specialisation that also demands a greater subdivision of land, has been addressed earlier as a theory of natural occupation (Marcus, 2000, 2001). This theory was proposed as a parallel to the theory of natural movement (Hillier et al., 1993). Each theory addresses one of the two generic functions of urban space identified by Bill Hillier (1996); movement and occupation, with movement primarily taking place in streets and other open spaces and occupation primarily taking place on plots that make up street-blocks. It is thereby suggested that the primary division of urban space seen in almost all cities between streets and blocks is a spatial reconciliation of the two generic but conflicting functions, movement and occupation (Marcus, 2001).

The theory of natural movement addresses the dependency between three variables: street network configuration, pedestrian movement and urban attractions (such as different land uses and density). Street network configuration is theoretically argued and empirically indicated as the main driver of the other two factors. Accordingly, street configuration distributes movement, which creates locations for attractions, which, in turn, may increase movement, and so on (cf. Hillier et al. 1993; Hillier and Iida, 2005). Hence, it is argued that natural movement is "the proportion of movement that is determined by the configuration of space itself, rather than by the presence of specific attractors or magnets" (Hillier et al 1993). A parallel argument in the theory of natural occupation is that natural occupation is “the proportion of occupation that is determined by the division of space itself, rather than by the presence of specific briefs or regulations” (Marcus 2001).

We see the theory of natural occupation as bridging Webster and Lai’s institutional theory of urban development with theories in urban morphology (highlighting the importance of plot systems for urban processes, as discussed in Section 4). It suggests that the structure and shape of plot systems may have an active role concerning the concentration of occupational uses of urban space, both in terms of built form, as described in the burgage cycle concept (Conzen, 1960) and in terms of diversification of activity, as described in the theory of natural occupation (Marcus, 2001).


1
2
3
4
5
6
0,25
0,2
0,15
0,1
0,05
0
400
1200
2100
3000
3800
6000
8200
10400
12600
14700
16900
19100
21300
23500
25600
27800
30000

Section 3

Methodological framework

3. 1 Traditional urban morphology and quantitative approaches to morphological analysis

To properly test the theory of natural occupation, as well as other morphological concepts addressing plot systems, precise descriptions and measures that effectively capture the morphological properties of plots and plot systems need to be developed. Within the field of urban morphology, there have been several such attempts. One often refers to three schools here: 1) the English or Conzenian school (Conzen, 1960; Slater, 1981; J. Whitehand, 2001), 2) the French or Versailles school (Choay, 2017; Lefebvre et al., 1996; Panerai, 2004) and 3) the Italian or Muratorian school (Caniggia and Maffei, 2001; Cataldi et al., 2002), as thoroughly discussed by Moudon (1997, 1994). Although they all differ, Moudon identifies many similarities between the schools (ibid.). All of them recognise three basic components of urban form (streets, plots and buildings) and all three study urban form across all scales, often involving the study of types. Importantly, they also have a strong focus on the temporal evolution of urban form, which is to say they often take the form of historical studies.

Although all three schools recognise plots as one of the three fundamental elements of urban form, the English school studies plots more explicitly and often in isolation. It originates from micro-scale geographical studies of settlements and the development of 'town-plan' analysis by Conzen (Whitehand, 2001). In Conzen's classical study of Alnwick, a town in Northumberland, the plot has a role in the burgage cycle concept (Figure 3.2) and is discussed more extensively below (Section 4.1).

FIG. 3.1 Multiscalar street types, developed by Serra (2013) as a demonstration of quantitative approach in urban morphology.

The French school has a stronger focus on relations between urban form and social processes (Choay, 2017; Lefebvre et al., 1996; Panerai, 2004) and, like the English school, considers the analysis

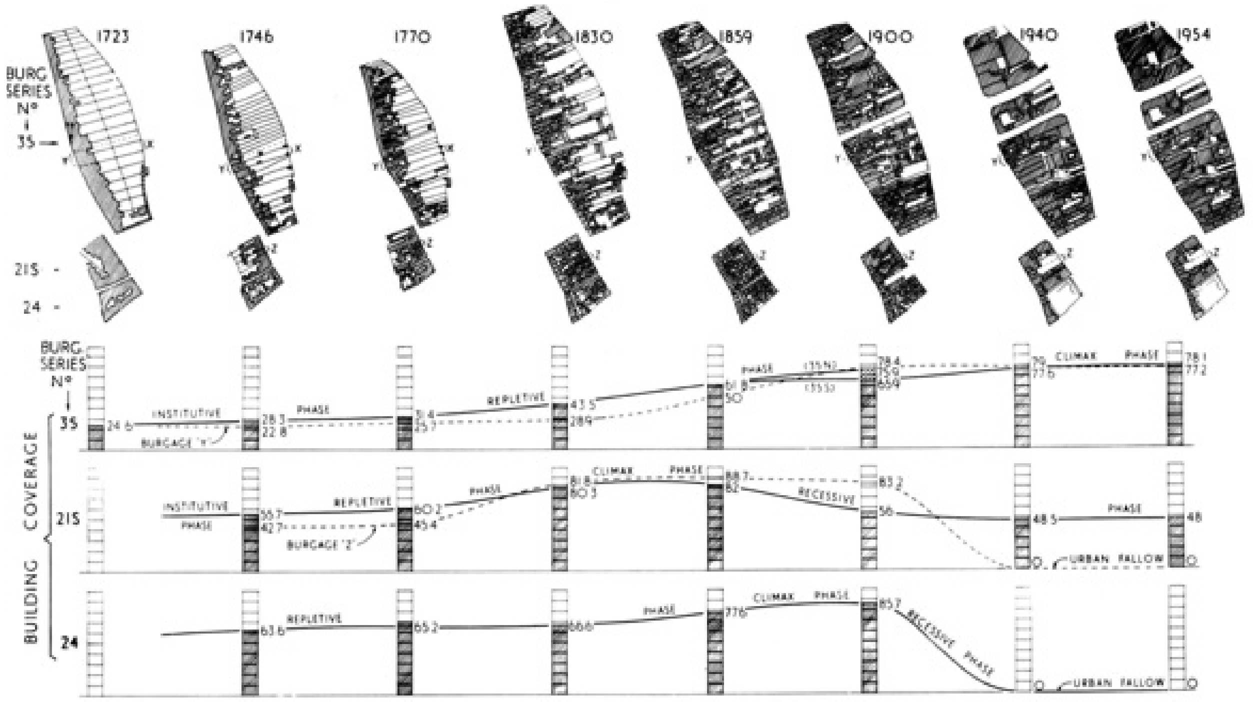


FIG. 3.2 Illustration of Conzen's burgage cycle concept: spatial and legal framework of the plot, which conditions the intensification of built space over time (study of Pilgrim Street, Newcastle-Upon-Tyne; Conzen, 1954).

of plots as central in explaining the correlation between space and society, especially when it comes to built form and public space (Panerai, et al., 2004).

In the Italian school, plots are not studied as much as a separate element, but often in close conjunction with buildings, where the historic description of building types (and their attachment to plots) has formed the idea, developed by Muratori and Cannigia, of an ‘operational history’, which aims to guide new urban development (Caniggia and Maffei, 2001).

Generally speaking, morphological studies within these schools have most often involved qualitative analysis of urban form, often limited to the study of ‘traditional’ urban fabrics (Berghauser Pont and Marcus, 2015a; Levy, 1999; Serra and Pinho, 2013). However, quantitative approaches to urban form have also developed outside these schools, such as the influential work of Martin and March (1972) (Figure 3.3). This quantitative approach was first described as a direction in urban morphology by Moudon in 1992; she refers to it by the term ´space morphology´ (Moudon, 1992). Other scholars mentioned by Moudon (ibid.) as representing this direction are Hillier and Hansson (1984) and Steadman (1983).

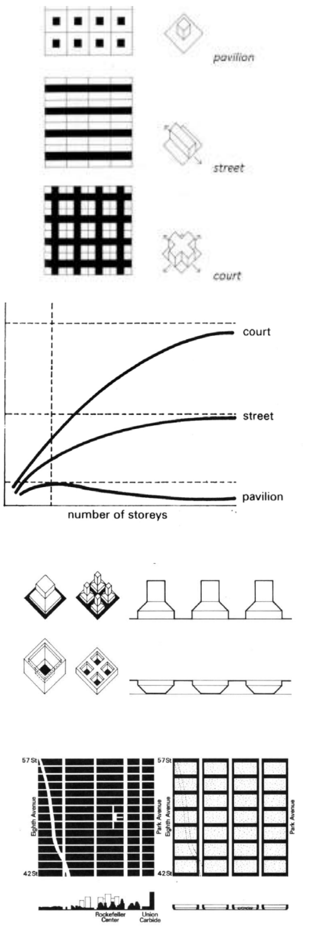


FIG. 3.3 Quantitative analysis of built forms; Martin and March, 1972

They all seek to uncover the fundamental characteristics or urban geometries by quantitative means (Moudon, 1992). The recent books by Batty (2018) and D'Acci (2019) may also be seen as representing the same direction. This approach is also central to the work of the SMoG (Spatial Morphology Group) research group, within which this thesis has been written. The group refers to this direction by the term 'spatial morphology'[6], and explicitly aims to combine and even integrate the approaches of traditional urban morphology with analytical and quantitative approaches to urban form; not least the configurational approaches of Space Syntax.

6. Contributions worth mentioning in this respect have been recently developed within the project Spatial Morphology Lab (SMoL), which this thesis is a part of. It was conducted in 2015-2018 in Chalmers University of Technology, Gothenburg, Sweden and financed by Chalmers foundation. SMoL project aimed at developing comprehensive descriptions and measures of the three fundamental components of urban form: street networks, building patterns and plot systems, with the goal to better understand their relationship with a variety of socio-economic processes in cities, such as social segregation, economic clustering and biodiversity loss.

Quantitative approaches to plots and plot systems, particularly those drawing on Space Syntax, have been presented by Marcus (2000, 2001, 2010). Their aims were to a) develop a variable of spatial differentiation in urban morphology, which they propose would capture the capacity of urban form and carry differences (see Section 4.1) and b) investigate the relation between such a variable and urban processes, especially economic diversification. There are several studies that build on Marcus' spatial capacity concept (Cantarino and Netto, 2017; Dovey et al., 2017; Feliciotti et al., 2017, 2016; Oliveira, 2013; Oliveira and Medeiros, 2016; Sayyar and Marcus, 2013). Although these studies offer interesting insights, they mostly study plots in conjunction with other components of urban form, which means they do not specifically contribute to the understanding of plot systems (cf. Morpho measures; Oliveira, 2013; Oliveira and Medeiros, 2016; Sayyar and Marcus, 2013).

Further, there are several interesting Asian studies (Asabere and Harvey, 1985; Asami, 1995; Asami and Niwa, 2008; Gao and Asami, 2007; Maniruzzaman et al., 1994) that offer an extensive quantitative exploration of plot systems. However, they are limited to a particular interest in land and real estate development and are therefore very specific. A more comprehensive and generic quantitative description of plots has so far not been developed within the field of urban morphology. This thesis aims to remedy this. The descriptions developed in this thesis include morphological measures of plots (Paper 1 and Sections 4.1 and 4.2), as well as plot types (Paper 3 and Sections 4.4 and 6). The importance of developing typological descriptions in urban morphology is specifically discussed in the subsection that follows.

3. 2 **Power of typological descriptions in urban morphology**

When it comes to the field of urban morphology, typological descriptions of urban form have been central. This is consistent with the fact that most directions in urban morphology are rooted in directions of architecture and geography influenced by the humanities, as touched upon in the subsection above. The central concern has therefore been the interpretation and understanding of complete urban entities and their meaning, be that the historic evolution of an entity or comparisons between such entities. This contrasts with the quantitative approach, with its origins in the natural sciences and concern for analysing an intrinsic logic of urban entities, without giving any prior meaning to them, but studying urban elements as in the 'lab' conditions by measuring, quantifying, translating them into variables and finally relating this variables to particular performances.

The approach we take in this thesis is to draw upon both; firstly, by developing measures for different morphological aspects of plots and plot systems, so that we can control the role of each individual aspect and relate it robustly to different urban processes. The strength of this method is that we can create strong ties between morphological aspects and, say, economic aspects, for instance, the differentiation of plots and concentration of economic activity. However, this may come at the cost of losing sight of the whole, which is the strength of the type. In principle, the type is not identified by a set of factors underpinning it, but rather by the idea behind the whole. In the words of the architectural theoretician Quatremere de Quincy, often referred to in this context, "the word 'type' presents less the image of a thing to copy or imitate completely than the idea of an element which ought itself to serve as a rule for the model" (1999). Harvey further adduces this, stressing the importance of types, or what he refers to as 'classifications', in developing abstract representations of reality. He states that it is “the basic procedure by which we impose some sort of order and coherence upon the vast inflow of information from the real world. ... [It is] may be regarded as a means of structuring reality to test hypothesis” (Harvey, 1969, p. 326)

We thus see that there are many occasions, not least in the practices of urban planning and design, when we need to speak about wholes and not just particular factors expressed in, say, a set of measures.

That is why typologies and classifications are recognised as a critical element of inquiry both in urban morphology (Moudon, 1994; Scheer, 2017, 2016) and in urban geography (Harvey, 1969; Wilson, 2000). Scheer (2016) further argues that it is one of the primary methods in urban morphology, while Harvey (1969) and Wilson (2000) discuss classification as fundamental to any type of urban analysis. It is a way in which morphologists can productively share their analyses and make cross-cultural comparisons, allowing them to distinguish similarities or differences between or within cities (Scheer, 2016) It further offers an economic means of data conceptualisation, as it allows for a combination of several coexistent or interrelated categories or data variables (Harvey, 1969; Wilson, 2000).

However, there are also weaknesses when it comes to typological approaches, especially as they are often based on qualitative assessments broadly agreed upon by society, but not always properly grounded. For example, they may be based on historical origin, geographic location or architectural style, with examples such as organic or planned cities, historic city centres or modernist suburbs, and so on. Further, as outlined by Serra and Pinho (2013), classifications of this kind often particularly concern the study of historic city centres, where there are established delineations and patterns of plots, buildings and streets (Caniggia and Maffei, 2001; Conzen, 1960, 2009; Marshall, 2005; Oliveira et al., 2015; Whitehand et al., 2014). This is not the case for the large variety of urban form we find in modernist areas, which have been far less studied in traditional urban morphology.

It is, therefore, becoming increasingly common to develop other kinds of typologies with analytical or algorithmically defined types based on similarities in terms of geometry, organisation or function. Typologies of this kind allow the description, not only of established urban forms found in historical cores but any possible kind of urban forms which constitute our contemporary cities. These more analytical approaches increasingly employ data-driven or unsupervised classification methods as discussed in Paper 3 (Bobkova et al., 2019a). Such methods have three advantages. They allow for the study of large datasets and the classification of urban form in all its diversity. These include modernistic and contemporary examples, which have proven challenging for traditional methods (Serra, 2013). They also allow the inclusion of a rich set of variables to generate the types; something not possible with traditional, visually defined methods of urban morphological analysis. Some recent contributions using this kind of data-driven classification to examine geometric attributes (Fusco and Araldi, 2017), configurational attributes (Barthelemy, 2017; Berghauser Pont et al., 2017; Serra, 2013, see also Figure 3.1) or combinations of these (Gil et al., 2012; Hausleitner, 2017). Finally, using such methods it is becomes rather easy to replicate analysis in other study areas or by other researchers.

3. 3 **Combination of deductive and inductive approaches**

The discussion on visually and algorithmically defined classification may be more broadly positioned within the discussion on deductive and inductive methodological approaches, in which algorithmic or data-driven classifications correspond to inductive approach, while traditional visual analysis may be related (in simple terms) to a deductive approach. According to Harvey (1969), deductive reasoning is highly determined by preselected criteria, assuming good existing knowledge of the studied phenomena. In inductive reasoning, patterns or regularities are explored without any presumptions or preselected theory. In other words, it is based purely on the data. (ibid.).

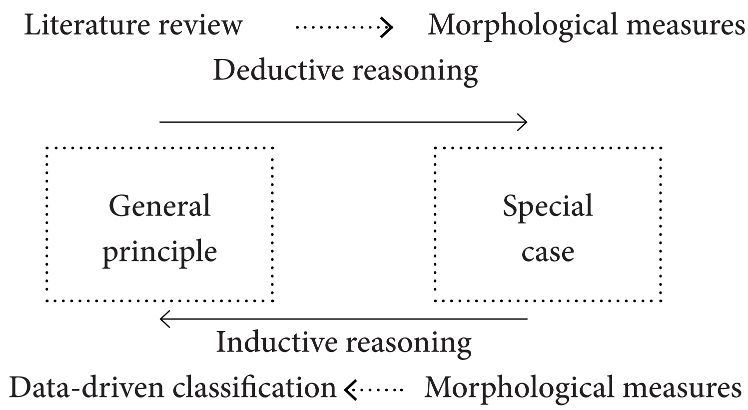


FIG. 3.4 Diagram illustrating methodological approach applied in this thesis.

In this thesis, deductive reasoning is used to develop the morphological measures of plot systems, relating them to established concepts in urban morphology. This is done to secure the morphological relevance of the chosen representations and measures, as will be discussed in Section 4.

At the same time, an inductive approach is used to detect plot types using data-driven classification based on the measures introduced and using the plot systems of five European cities as case studies (Bobkova et al., 2019a) (see also Section 6, Results and Atlas of Plots).

The proposed combination of deductive and inductive approaches (see Figure 3.4) allows us to position our study within quantitative urban morphology, which is theoretically grounded in traditional urban morphological studies, but simultaneously allows us to strengthen and scale up traditional urban morphological analysis to allow for large-scale cross-cultural comparisons of plot systems in different cities. Moreover, it provides the means to systematically test previously introduced theories, in both the urban morphology field and other fields addressing urban processes, such as urban planning and urban economics.

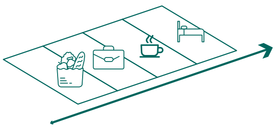
Institutional theory of urban development
(Webster and Lai, 2003)

Natural Occupation
(core theory)

(urban morphological concepts)

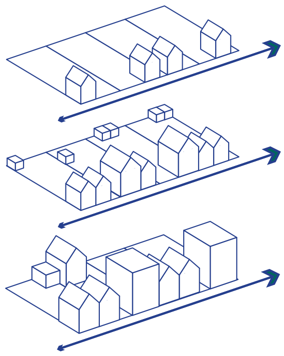
Plot in space

Urban diversity (Spatial capacity, differentiation of space; Marcus 2000,2010)



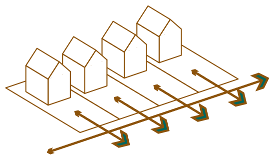
Plots in time

Evolution of built form over time (Burgage cycle; Conzen 1960)



Plots as interface

Link between local design decisions and global structure of cities (Vialard and Carpenter 2015)



Section 4

Measures and types of plot systems

4. 1 Concepts and measures

FIG. 4.1 General overview of the key concepts highlighting the importance of plot systems for urban processes in cities and their link to the theory of natural occupation

This subsection gives an overview of cornerstone concepts discussed in urban morphology that highlight the importance of plots for urban processes in cities (only briefly introduced earlier): ‘urban diversity’, ‘evolution of built form over time’ and ‘the public-private interface’. These concepts are further summarised as *plots in space*, *plots in time* and *plots as interface*. We see these concepts as supporting the theory of natural occupation, as introduced in Section 2 (See Figure 4.1). For each concept, we develop a spatial measure that will be used to develop plot types and test the theory of natural occupation.

Plots in space: urban diversity

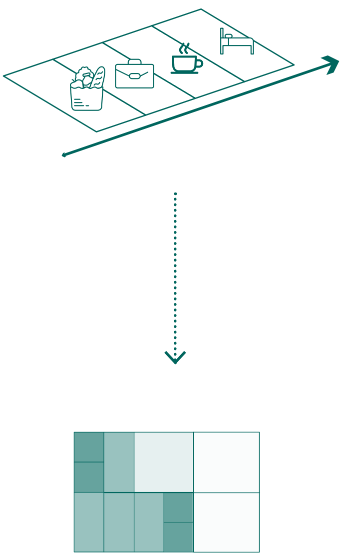
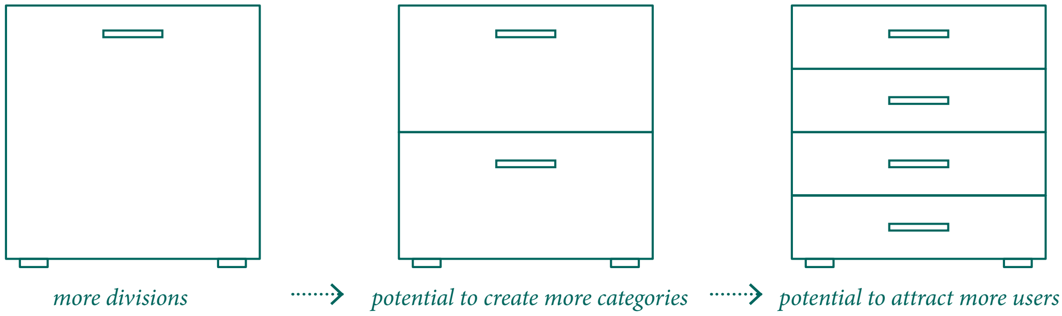


FIG. 4.2 'Plots in space', illustrative diagram

The argument behind the concept of spatial capacity (Marcus, 2010, 2000; Sayyar and Marcus, 2013), is that a high number of plots within an urban area provides a potential to host a higher number of owners and, in turn, owner strategies. For instance, concerning which economic activities to let space to, more strategies of this kind in an urban area create potential for greater diversity among these economic activities. Conversely, a low number of plots within an urban area is likely to create conditions for the opposite. This is conceptualised here as plots in space and is linked to the concepts of economic specialisation and knowledge diversification, as discussed by Webster and Lai (2003)

More generally, the central principle behind the concept is that in order to provide the potential for artefacts or uses to remain different, we need to introduce some sort of spatial division or differentiation between them. This might be drawers in a chest of drawers, which allow us to categorise clothes, or containers in a sweet shop, or divisions of agricultural land allowing the


more divisions
potential to create more categories
potential to attract more users
1.


2.


AUSTRIA
FORMER IRON
CURTAIN BORDER
SLOVAKIA
3.

FIG. 4.3 Illustration of spatial sapacity concept: 1. drawers in a chest of drawers; 2. containers in sweet shop (source: author's own); 3. agricultural divisions on two sides of former Iron Curtain border that distinct differences between Western Europe and former Socialist block countries (source: maps.google.com).

growing of different crops (Figure 4.3). In cities, plots allow us to designate different owners, uses or buildings to particular sites. The more urban land is divided into separate plots, the greater the opportunity to sort people, things or functions into a greater number of categories.

Marcus proposed to measure spatial capacity, or what here also is referred to as differentiation of space (Bobkova et al., 2019a; Marcus et al., 2017; Marcus and Bobkova, 2019), by counting the number of plots, accessible within a certain distance threshold or catchment area. In other words, *the accessible number of plots* (Marcus, 2010; Sayyar and Marcus, 2013). This measure is strongly related to plot size as, if the plots are smaller, there is normally space for more of them within a set distance. While this measure is relatively well-established in related literature (Feliciotti et al., 2016; Oliveira, 2013), there are no studies which investigate it specifically. In most cases, it is used in rather narrow case studies related to a particular context, or in combination with other components of urban form. In this thesis, both measures (*plot size and accessible number of plots*) are used to analyse the five case-study cities (Bobkova et al., 2017a).

Plots in time: evolution of built form over time

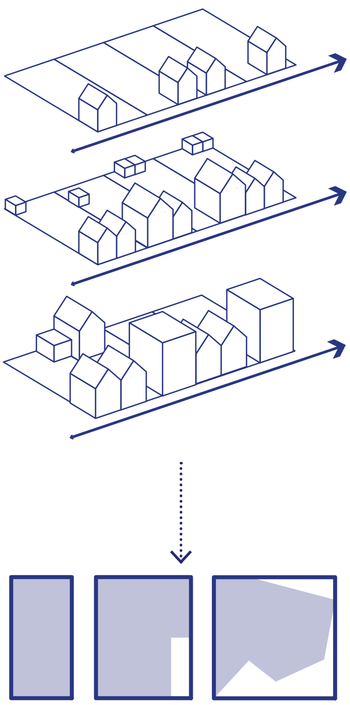


FIG. 4.4 'Plots in time', illustrative diagram

In urban morphology, plot systems lie at the core of the English (or Conzen) school, where they are understood to constitute the organisational framework for the evolution of built form over time. Within urban morphology, this is discussed extensively as the 'burgage cycle concept', which concerns the life cycle of the plot (Conzen, 1960). According to Conzen, the process of urbanisation results in the subdivision of plots into smaller plots, accompanied by their densification over time (ibid.). In other words, it describes the evolution of built space, as bound by the spatial and legal framework of the plot (Kropf, 2009). As outlined in Section 2, this concept is related to what Webster and Lai (2003) describe as the 'economic evolution' of cities. In this thesis, we refer to this evolutionary notion as *plots in time*.

A large number of studies originate from this basic idea, which

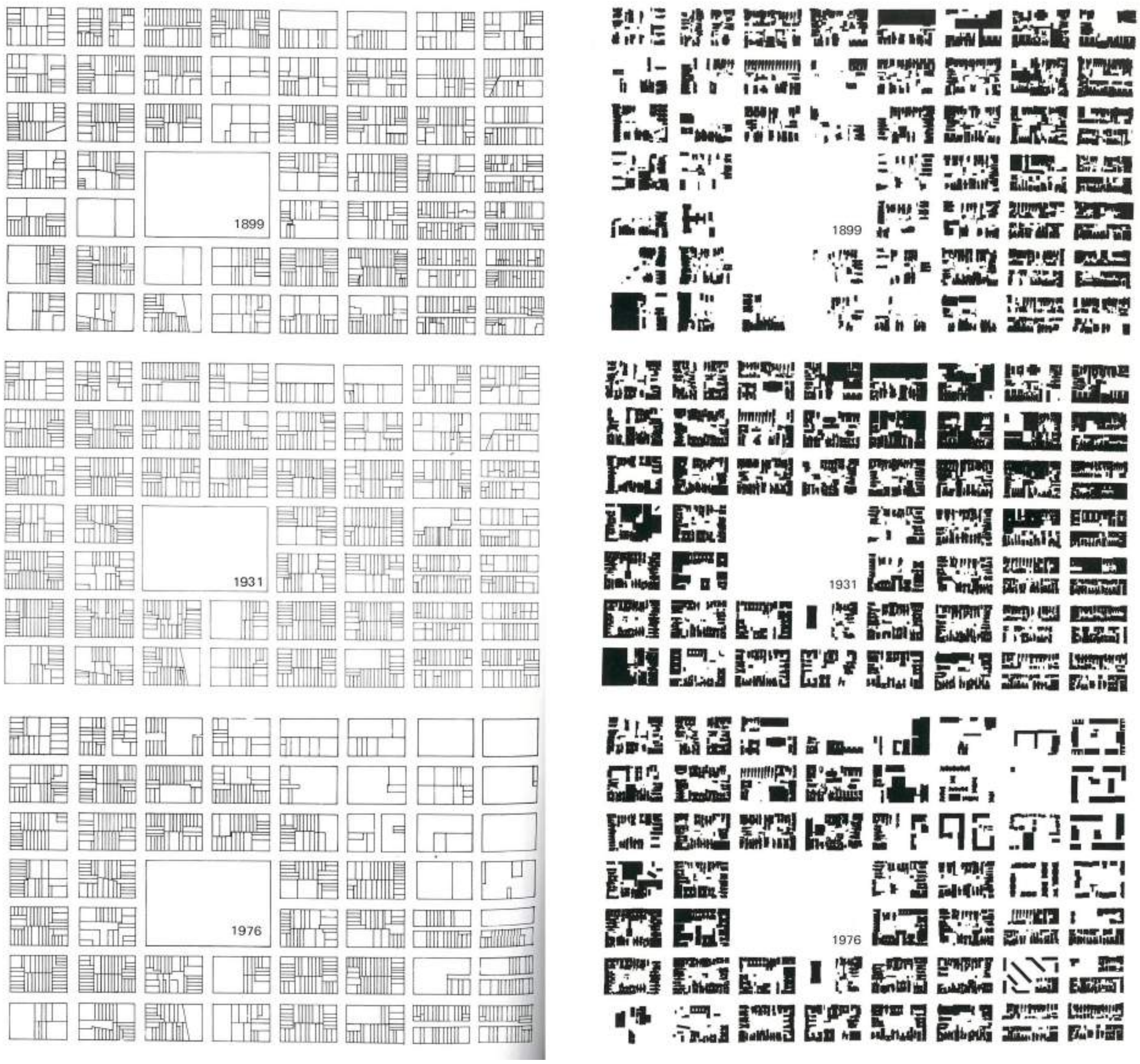


FIG. 4.5 Physical transformations in the San Francisco's urban fabric (Moudon, 1986)

explores the temporal transformation of traditional urban fabrics (cf. Chen, 2012; Ersland, 2010; Slater, 1981; Ünlü and Baş, 2017; Zhang, 2015; Zhang and Ding, 2018). One of the most influential studies in this area is Moudon's work, "Built for change" (1986), in which she extensively studied physical transformations in the urban fabric of San Francisco (Figure 4.5). She discussed how small plots support urban resilience, allowing many actors to be direct participants of development processes and make different decisions, hence ensuring variety and diversity in the urban environment (ibid.). Further, she pointed out that development based on small plots slows the rate of change, because it makes large-scale real estate transactions more difficult (ibid.).

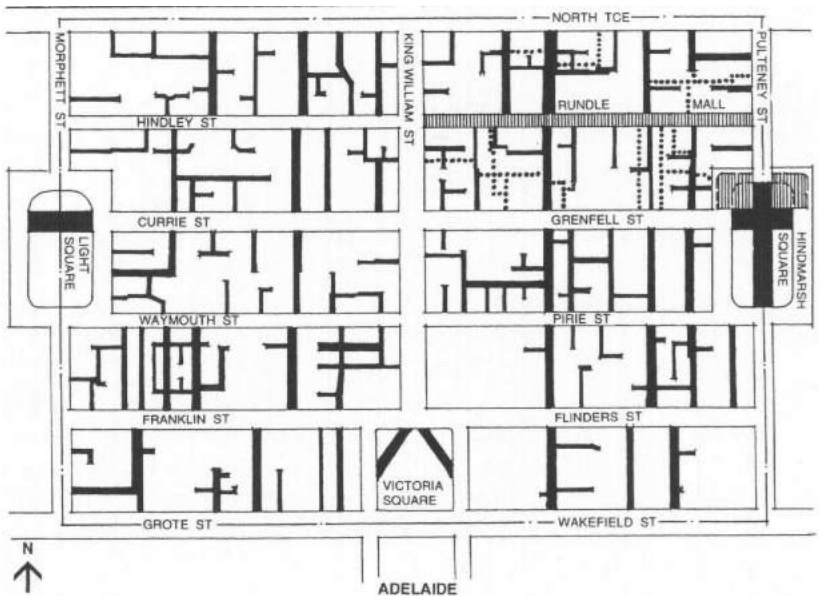


FIG. 4.6 Modifications of urban fabric in Adelaide (Siksna, 1998)

Most of the studies originating from the burgage cycle concept are related to the temporal transformation of plot sizes (cf. Zhang and Ding, 2018) and discuss how plots become smaller as a result of urbanisation processes. Other studies show that plots may also get bigger, to accommodate large-scale developments such as CBDs, housing estates or shopping malls; something rather common in the 20th Century (cf. Siksna, 1998, Figure 4.6). In Paper 1 (Bobkova et al., 2017a) and following previous findings by Siksna (1998) and Vialard (2012), it is argued that the ability of the urban fabric to adapt to land-use changes is also related to the degree to which plots are able to amalgamate into bigger plots or to divide into smaller ones (Bobkova et al., 2017a). It is therefore suggested that it is not only the particular plot size, but its divisibility, which is important to creating flexibility in plot systems and allowing for temporal transformation (ibid.) and that this aspect can be captured with the degree of plot compactness.

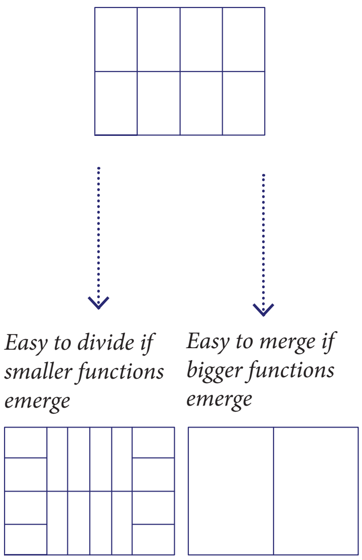


FIG. 4.7 Illustration of plot divisibility concept

For this reason, it is considered important to add an additional measure of *plot compactness* that captures the aspect of plot *divisibility* that potentially further contributes to changeability of land uses over time (Figure 4.7).

Interestingly, a range of Asian studies not directly related to traditional urban morphology (and also referred to in Section

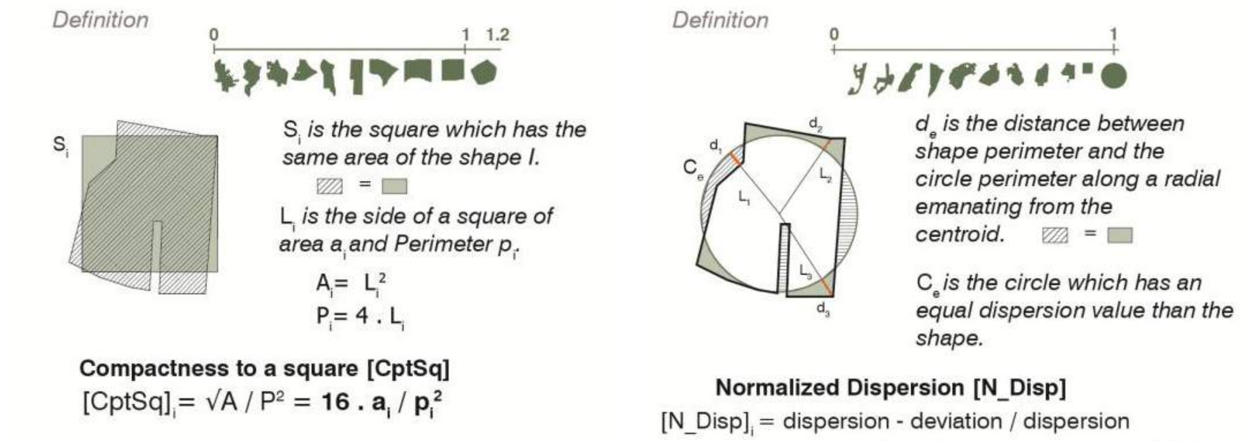


FIG. 4.8 Block measures proposed by Vialard (2013). Compactness by square (on the left) and compactness by radials (on the right).

3.1) focus mainly on historical analysis of traditional human settlements, which deal with plots in relation to land redevelopment (Asabere and Harvey, 1985; Asami and Niwa, 2008; Maniruzzaman et al., 1994; Usui, 2018). These studies offer interesting quantitative descriptions of plot shapes and often measure plot compactness (Asabere and Harvey, 1985; Asami, 1995; Asami and Niwa, 2008), with the most compact plot understood to be the one closest in shape to a circle. Because these studies deal with the transformation of existing urban fabric, they may be broadly positioned within the *plots in time* concept.

In her study of block faces[7], Vialard proposes capturing the degree of shape compactness, not only in relation to the circle but also to the square (Vialard, 2013, see also Figure 4.8). Following Vialard, this thesis measures the divisibility aspect of plots using the index of plot compactness (Bobkova et al., 2017a), which is, in our case, the ratio between plot area and the area of the minimum rectangle bounding that plot (see Table 1 and Atlas of Plots). The reason for choosing this index is that in the case of plots, the most rectangular, rather than circular, shape may be described as the most compact, since a rectangular shape allows plots to be joined together in the most efficient and compact way.

7. Though Vialard in her dissertation (2013) mostly focuses on the study of blocks and block faces, and only to a smaller degree focuses on plots (Vialard, 2012; Vialard and Carpenter, 2015), we find that her geometrical measures can also, to certain degree be applicable to the study of plots.

Plots as an interface: public-private interface

The third concept, plots as interface, is the least established among the three being applied in this thesis. It was first discussed by

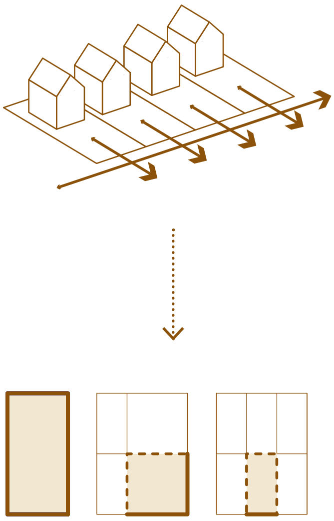
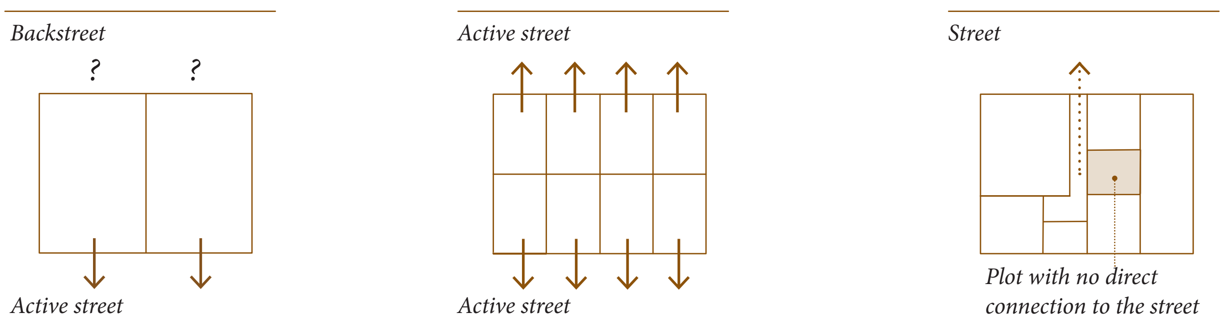


FIG. 4.9 'Plots as interface", illustrative diagram

Panerai et al. (2004), who stressed the dialectical relationship between the plot and the street network, with the plot serving as the connection between the space for building and the space for movement. Vialard and Carpenter (2015) describe the street boundary of the plot as an interface between local design decisions, such as buildings, and global urban structures, such as streets. Vialard's (2013) main focus is block-faces. Nevertheless, we see it as a powerful contribution to the discussion about plots. This is because it captures the interaction between public and private spaces, with respect to the quality of public spaces and active street life. It also refers back to Jacobs' (1961) concept of 'eyes on the street', in which plots with narrow frontages often correlate to the presence of higher number of entrances and, hence, to visual permeability between plots and streets (Alonso de Andrade et al., 2018).

The concept is illustrated by the Figure 4.10, that demonstrates possible implications for active street life, depending on the proportion of plot frontage in relation to the street . As more explicitly discussed in Paper 1 (Bobkova et al., 2017a), the high degree of plot frontage ratio (Figure 4.10a) may indicate that public space of the street is overrepresented in the studied area and hence might be underexploited. On the opposite, once a plot has limited or no access to the street (Figure 4.10c), which is a rather common situation for post-war neighbourhoods), this, in turn, might indicate that the space of this plot itself is underexploited, meaning decreased potential of active use of this plot (ibid.).

FIG. 4.10 Plots in relation to street public space



a. Inactive street on one side of the block: public space is underexploited

b. Active street on both sides of the block

c. Plot does not have direct connection to street space: plot space is underexploited

SHAPE	Width : Depth
X-NARROW	>1:5
NARROW	1:5 - 1:2
BROAD	1:2 - 1:1

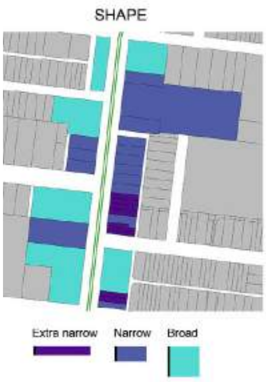


FIG. 4.11 Width to depth ratio as a way to capture plots as interface (Dovey et al., 2017)

Although the most common way to measure plots as interfaces is to use the plot-width-to-plot-depth ratio (Dovey et al., 2017, Figure 4.11), we only find it adequate for traditional, rectangular plots. For plots of other geometric shapes, there is no allowance for upscaling or measuring of this interface.

Hence, in this thesis (Bobkova et al., 2017a), we propose to measure the public-private interface by relating the plot's street frontage length to its total perimeter. We call this measure the 'plot frontage index' [8].

4. 2 **Summary of existing knowledge gaps**

To summarise, while there is a variety of existing plot measures found in the literature (see Table 1), there is no consistency in how these measures are used. Several drawbacks of the current use of plot measures can be outlined as follows.

Firstly, some measures, such as plot width to depth ratio, are only relevant for particular contexts and are hard to upscale in order to describe all possible kinds of plots: the problem that complicates spatial analysis, if the researcher is interested to conduct the study involving the large amount of urban data, covering, for instance the whole city or metropolitan region.

Secondly, there are commonly used measures (such as measure of compactness, often used in Asian studies) that either relate the most 'optimal' shape to something that is found in a particular urban context and hence are difficult to use for conducting cross-cultural comparisons; either propose mathematical description of the measure, that does not directly correspond to the morphological concept of our interest (capturing divisibility aspect by relating the most compact shape to a rectangle).

Thirdly, different geometrical parameters are sometimes argued to capture the same phenomenon (for example temporal evolution of urban fabric, see table 1), or the same geometric parameter is argued to capture different phenomena. This means that there is no

8. In Papers 1 and 2 (Bobkova et al., 2017b, 2017a) 'plot frontage index' is referred to as 'plot openness'. The index name has been changed, so that the audience would not confuse it with Open Space Ratio often used as one of the density measures (Berghauser Pont and Haupt, 2010) general agreement on which aspect actually contributes to which of the urban processes described above. This problem calls for an empirical investigation that would allow to explore which measure best captures what phenomena. However, we argue that there is lack of solid theoretical ground to do this and therefore chose to synthesize the state-of-the art in a set of three measures grounded in urban morphology theory.

Finally, following the Occam's razor principle 'if something can be described in more simple terms, it should be done so', one would be interested to develop the smallest number of measures capable of capturing the targeted aspects in the most economical way. This could be something similar to Floor Space Index (FSI) and Ground Space Index (GSI) developed by Berghauser Pont and Haupt (2010), where any kind of building type can be captured by only two spatial measures.

As a response to these gaps, this thesis proposes three concepts of 'plots in space', 'plots in time' and 'plots as interface', that are broadly described in the subsection above (4.1). These concepts are complementary, in that each one describes a particular morphological characteristic of plots. Each one also forms the basis of one of the three measures that we have introduced (Bobkova, et al., 2017a; Bobkova, et al., in review; Bobkova, et al., in review), which are also summarised in Table 1, below.

Further, three geometric measures introduced in this thesis (Table 1) are then translated in accessibility measures, meaning that the same aspect is captured not for each individual plot, but as a generalised quality of a plot pattern surrounding each plot. The detailed description of accessibility measures, as well as the reasons for using those are broadly described in the following subsection.

Overview of literature discussing various plot measures

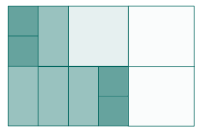
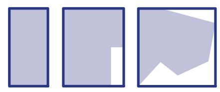
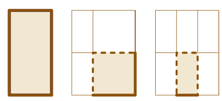
FRAMING THEORY AND RELATED TERMS	INTRODUCED BY...	SUPPORTING LITERATURE	EXISTING MEASURES	MEASURE AS PROPOSEIN IN PHD THESIS
Plots in space (spatial capacity) Also referred to as: differentiation (Bobkova et al., 2019a; Marcus et al., 2017)	Marcus 2000,2010	(Cantarino and Netto, 2017; Dovey et al., 2017; Feliciotti et al., 2017; Oliveira, 2013; Oliveira and Medeiros, 2016; Sayyar and Marcus, 2013	Plot size, accessibility to plots (Marcus, 2010; Sayyar and Marcus, 2013) Lot size (Dovey et al., 2017) Plots density per block (Oliveira and Medeiros, 2016) Plot size, accessibility to plots (Feliciotti et al., 2016; Oliveira, 2013) Plot size (Cantarino and Netto, 2017) Lot size (Kim et al., 2017) Plot size (Barbour et al., 2016) Plot size (Tarbatt, 2012) Plot area (Zeka and Yuzer, 2019) ADDITIONAL LITERATURE ADDRESSING SIMILAR MEASURES IN RELATION TO OTHER ASPECTS OF PLOTS (LAND VALUE, LAND REDEVELOPMENT) Lot size (Gao and Asami, 2007; Maniruzzaman et al., 1994) Lot shape (Gao and Asami, 2007)	**Plot size** 
Plots in time (Burgage cycle) Also referred to as: Plot persistence (Ersland, 2010) Modularity, resilience (Feliciotti et al., 2017)	Conzen, 1960; Moudon, 1984	(Asabere and Harvey, 1985; Asami and Niwa, 2008; Chen, 2012; Ersland, 2010; Feliciotti et al., 2017; Gao and Asami, 2007; Maniruzzaman et al., 1994; Osaragi, 2014; Siksna, 1998; Slater, 1981; J. White-hand, 2001; Zhang, 2015; Zhang and Ding, 2018)	Frontage width modification over time (Slater, 1981) Lot width and depth (Siksna, 1998) Plot size, accessibility to plots (Feliciotti et al., 2017) Plot size (Zhang and Ding, 2018) ADDITIONAL LITERATURE ADDRESSING SIMILAR MEASURES IN RELATION TO OTHER ASPECTS OF PLOTS (LAND VALUE, LAND REDEVELOPMENT) Lot size and lot compactness (Maniruzzaman et al., 1994) Compactness calculated in relation to circle Lot compactness as related to circle (Asabere and Harvey, 1985; Asami, 1995; Asami and Niwa, 2008)	**Plot compactness index** (plot area divided by the area of its minimum bounding rectangle) 
Plots as interface (Interaction between local design decision and global structure of cities) Also referred to as: Public/private interface (Dovey and Wood, 2015)	Panerai, 2004; Vialard, 2012	(Alonso de Andrade et al., 2018; Dovey et al., 2017; Dovey and Wood, 2015; Sevstuk et al., 2016)	Plot frontage width and depth (Sevstuk et al., 2016) Plot frontage width (Kim et al., 2017) Plot width to depth ratio (Dovey et al., 2017) Plot proportion (Zeka and Yuzer, 2019) ADDITIONAL LITERATURE ADDRESSING SIMILAR MEASURES IN RELATION TO OTHER ASPECTS OF PLOTS (LAND VALUE, LAND REDEVELOPMENT) Lot frontage to depth ratio (Colwell and Scheu, 1989) Lot frontage to depth ratio (Osaragi, 2014)	**Plot frontage index** (plot street length divided by plot total perimeter) Also referred to as: Plot openness index (Bobko-va, et al., 2017a; Bobkova, et al., 2017b) 

TABLE 1. Overview of existing plot measures as found in the literature

4. 3 **From geometric to accessibility measures**

The aim of this thesis is to develop comprehensive quantitative descriptions of plot systems that are applicable to a variety of contexts; comparable to today's powerful descriptions of building patterns and street networks. Regarding the former, Martin and March (1972) introduced a theory about the relation between urban density and three generic building types (blocks, slabs and detached houses). This was further developed by Berghauser Pont and Haupt (2010), who developed a multi-variable approach to built density measures (Figure 4.12); applying it enabled them to validate Martin and March's theory empirically (Steadman, 2014).

When it comes to street networks, there have been important quantitative contributions not least from Space Syntax research (Hillier, 1996; Hillier and Hanson, 1984). Importantly, Space Syntax differs from more traditional geographic descriptions, in which different entities typically are described as densities within areas defined under different principles, such as grids or administrative units. Instead, the approach is configurational, principally concerned with analysing the relation between the parts and the whole. Further, the actual analysis often takes the form of network analysis, particularly the use of different measures of network centrality. This has since been extended into Place Syntax analysis (Ståhle, 2008). It still uses the typical distance measures of topological and angular distances developed in Space Syntax, but further extends it not to only the centrality of the street network itself but also how it creates accessibility to different attractions

Floor Space Index (FSI)
$FSI_x = F_x / A_x$ where

F_x = gross floor area (m^2)
A_x = area of aggregation x (m^2)
x = aggregation (lot (l), island (i), fabric (f), or district (d))

Ground Space Index (GSI)
$GSI_x = B_x / A_x$ where

B_x = footprint of (m^2)
A_x = area of aggregation x (m^2)
x = aggregation (lot (l), island (i), fabric (f), or district (

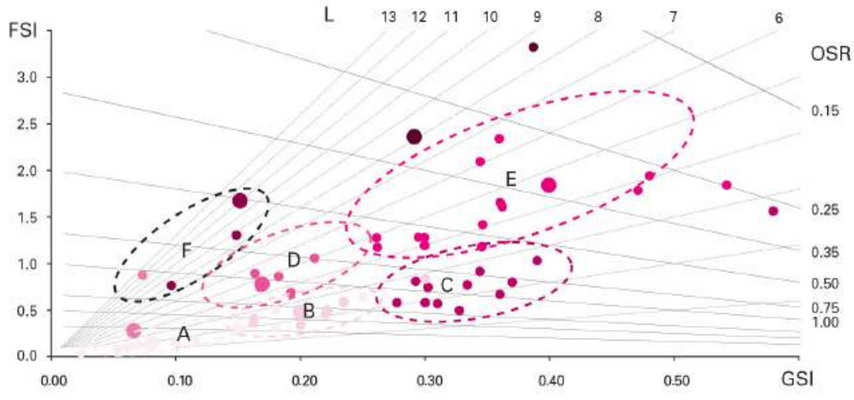


FIG. 4.12 Spacematrix developed by Berghauser Pont and Haupt (2010)

in the city, anything from residents to restaurants. In this context, we see shifts within Space Syntax research from configurational analysis, through network analysis, to accessibility analysis. It is important to keep track of these.

Accordingly, in addition to the traditional geometric or 'area-based' measures discussed in Section 4.1, this thesis also uses accessibility or 'location-based' measures[9]. There are several reasons for this. Firstly, although this thesis is also concerned with descriptions of individual plots, a central aim is to capture the important properties and qualities given to the individual plot by its location within a plot system; something often overlooked in many descriptions of morphological components. Secondly, we can circumvent many of the problems related to MAUP (Modifiable Units Problem) (Openshaw and Taylor, 1979), concerning scale (aggregation) and the zonation effect[10] (See Figure 4.13). Thirdly, accessibility measures of this kind, especially when measured by following the actual street system, are arguably more lifelike. This is because they measure entities in cities as they are located and accessible to a person moving through urban space, whereas area-based descriptions are hard to relate to any actual agents in urban space.

9. Geometric and accessibility measures may be also referred to as 'area-based' and 'location-based' measures (Berghauser Pont and Marcus, 2014; Bobkova et al., 2017a).

10. The problem with the scale and zonation effect is that the larger the area of aggregation, the more variation is lost in the calculation. This, in turn, has an effect on the relevance of the results to urban design purposes, as they become more abstract (Berghauser Pont and Marcus, 2014).

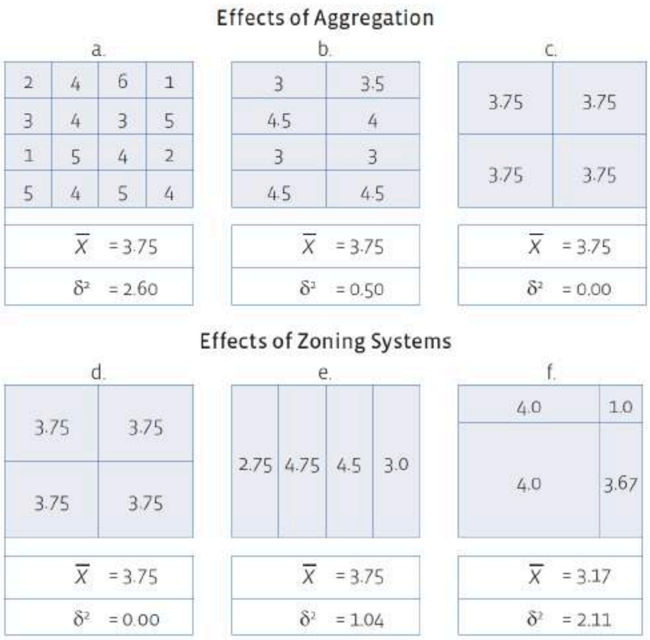


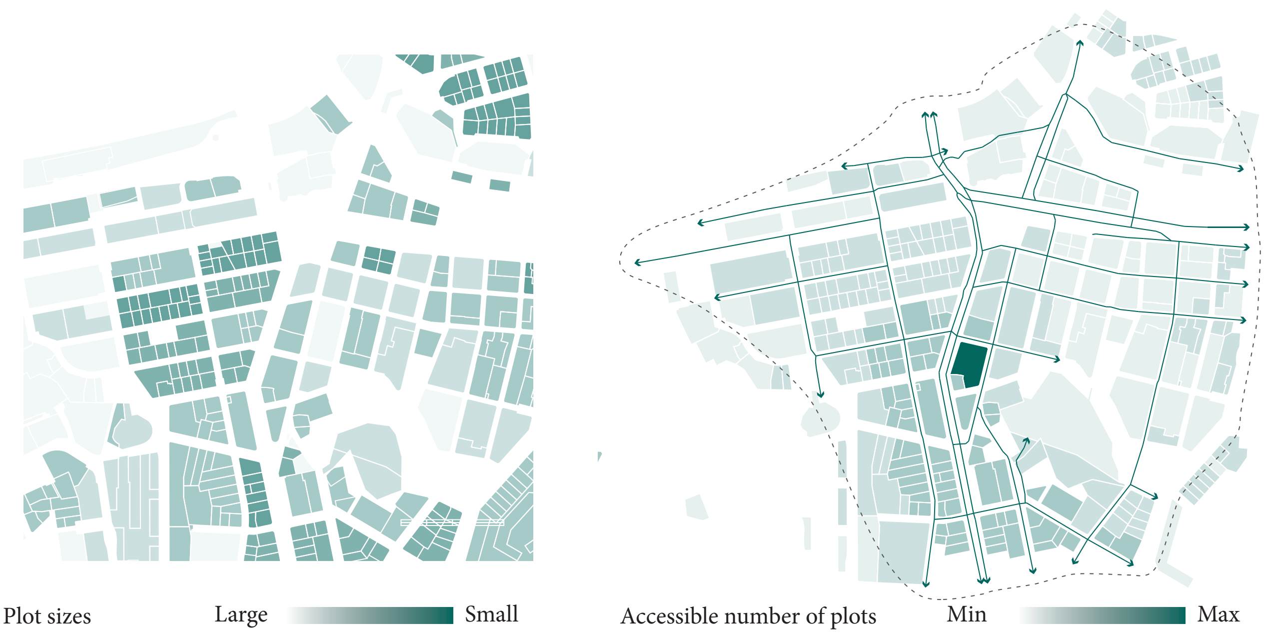
FIG. 4.13 Effects of scale and zonation on the mean value (x) and variance (δ^2) (interpretation of Jelinski and Wu, 1996, in Dark and Bram, 2007, p. 473).

This means that, besides the morphological measures that capture the geometric characteristics of individual plots, we also develop accessibility measures describing the character of the plot system, (Berghauser Pont and Marcus, 2015b, 2014; Ståhle, 2008). More specifically, we use the cumulative-opportunities accessibility measure (Bhat et al., 2000), with the distance threshold set to a 500m walking distance (for a detailed explanation of the measure, see Section 5 and the Atlas of Plots).

More precisely, this means that the measure of plot size is translated into the measure of accessible number of plots within a certain distance threshold; in this thesis, set to 500m walking distance (See also Figure 4.14). Similarly, the plot compactness index is translated into accessible plot compactness; describing how compact in shape the plots are within the set distance threshold. In turn, the plot frontage index is translated into an accessible frontage index, describing how much street interface plots have within the set distance threshold. The detailed description of plot measures, including development method, formulae and basic descriptive statistics for the five cities, is presented in Section 5 (Research design), Section 6 (Results) and in the Atlas of Plots.

To summarise, the use of accessibility measures instead of

FIG. 4.14 Diagram illustrating difference between geometric measures (on the left) and accessibility measures (on the right)



geometric or area-based ones allows to capture geographic locations in cities in a more advanced manner. While shifting from geometric measure of plot size to accessible number of plots, we still indirectly capture plot size (naturally the smaller plots are, the more plots can be access from a location). But, on top of this, we also capture contextual location of these plots in the city: setting 500m walking distance radius allows to distinct local centres in cities from the pedestrian or 'bottom-up' perspective, regardless their 'global' position in the city. Potentially, one could repeat the analysis using larger radii (this was tested in Paper 5, see Results, Section 6.3), capturing a more global accessibility of locations in cities, or even multi-scalar accessibility (both local and global centres). While this could be an interesting further elaboration of this thesis, our particular focus here was to capture plot patterns from the pedestrian perspective, that is why the measures are mainly translate into accessibility measures within 500m walking distance.

What is discussed above, is mostly relevant for the measure of accessible number of plots, that captures how many plots, in absolute terms, can be reached through the street network within a set walking distance from each plot in the city. But, as we argued, this method of measuring can also capture indices (the two other measures of compactness and frontage index).

On the one hand, such indices even out the differences between individual plots and, instead, capture the qualities of a particular pattern more generally (See Figure 4.15). There are several advantages of this method, both for analytic and design purposes. For analysis, it helps us focus on the understanding of contextual and general qualities of neighbourhoods in the city. From the urban design perspective, it withdraws the attention from particularities to general patterns; instead of designing individual plots, we should design the patterns or plot systems.

Having said this, individual plots and geometric measures are still important, because when one designs a pattern, one also has to be able to operate with 'the building bricks' that constitute the pattern.

a. Plot compactness Index

b Accessible plot compactness Index

0 1

0 500 1000 m

FIG. 4.15 Plot compactness index in Sotckholm captured a) as geometric measure(per each individual plot) and b) as accessibility measure (capturing general quality of the patttern).

Furthermore, land use regulations and zoning codes exist are obviously easier to relate to geometric, not accessibility measures. These aspects of the individual plots would ideally be linked to the plot patterns discussed in this thesis, which could be an interesting continuation of the work presented here.

Nevertheless, even by recognising the importance of geometric or area-based measures of plots, we still see the shift to accessibility or location-based measures as critical one both to analyse or to design plot patterns in cities. Here, the notion of how repetitions of plots form together plot systems and relate to other plot systems in neighbouring areas, lies at the core of the our understanding of cities not as the archipelago of individual things, but as the relations between the many parts that together form the wholes in all their complexity.

4. 4 **Existing typologies of plot systems**

As discussed in Paper 3 (Bobkova et al., 2019a), few studies address the issue of plot classification based on quantitative variables and have mostly been developed within the field of landscape ecology. For example, the study by Fialkowski and Bitner (2008) proposes a generic classification of plots into three categories based solely on plot size distribution. While useful for landscape ecology purposes, this classification lacks architectural precision as all plots are classified as either urban, suburban or rural. Demetriou, et al.

(2013b, 2013a) propose a multi-attribute classification of parcel shapes. However, this comprehensive classification was developed for very particular purposes related to optimum parcel shape required in land consolidation projects. Hence, it is both normative and limited. Within the field of urban design, Tarbatt (2012) proposed a generative classification of plots. However, this was limited to the particular context of design practice in the UK and only covered fine- and medium-grain rectangular plots.

When it comes to studying plot types in urban morphology, the number of studies that address it comprehensively are also few and based mainly on visual assessments (Ünlü and Baş, 2017; Zhang, 2015). In addition, plot systems are rarely studied in isolation and mostly combined with other components of urban form (Feliciotti et al., 2017; Kropf, 2017; Scheer, 2001).

In this thesis, we therefore fill this methodological gap by developing comprehensive typological descriptions of plots, following the methodological framework introduced in Sections 3.2 and 3.3: inductive, data-driven classification of morphological measures of plots, developed on the basis of central concepts in urban morphology (Section 4.1 and 4.2, Paper 3, Bobkova et al., in review). The technicalities behind this procedure are described in detail in Section 5 (Research Design), and a detailed overview of the resulting types is presented in Section 6 (Results).

Plots
Form + Behaviour

Original ambiguity of the term

Separating form from process
Developing legal morphological definition of plots

Step 1

From plots data to plots representation

Conceptualising urban morphological theories into spatial measures

Step 2

Developing spatial measures of plots

Combining spatial measures into typologies

Step 3

Typological descriptions

Testing measures and types against earlier introduced theories

Step 4a and 4b

Exploring non-formal linkages
(Testing theories)

Section 5

Research design

5. 1 General overview of methodological steps

The research design of the thesis is based on the epistemological framework proposed by Scheer (2016). Her epistemological schema includes data selectivity and collection, pattern recognition (or, what we, in this thesis refer to as 'typological descriptions'), theories of change and finally exploration of non-formal linkages between urban form and urban processes (ibid.). All these steps (except theories of change, which require temporal data on plot systems and are therefore beyond the scope of this thesis) constitute the narrative of this thesis and are explained below.

For data selectivity, which we further refer to as 'representations of plot systems', the principal question is how we define plots morphologically. In other words, which attributes of plots should be chosen as the most suitable for the questions central to this thesis. This issue is related to the ambiguity behind many dimensions of the term 'plot' discussed in the introduction (Section 1) and in Papers 1 and 2 (Bobkova et al., 2017a, 2017b). In this thesis, our definition of plot systems is developed within the framework of the theory of 'natural occupation' introduced earlier and may be referred to as a 'legal-morphological' definition of plots. The plot systems addressed in this thesis are defined as 'plots on land intended for long-term occupational use'. That is, plot systems typically found within street blocks, as opposed to plots on land used for movement, such as streets, or plots on land used for temporary occupational purposes, such as public places. The methodology of data selectivity and collection according to this definition is described further in Section 5.2 (Step 1).

Next, the quantitative descriptions of plot systems are developed. These descriptions include the development of measures of morphological variables of plots and plot systems (Paper 1,

FIG. 5.1 Research design of the thesis (methodological steps)

(Bobkova et al., 2017a) and the combining of these variables into typological descriptions (Paper 2, (Bobkova et al., 2019a). The methodology related to this is further described in Sections 5.3 (Step 2) and 5.4 (Step 3) respectively.

Finally, the developed descriptions of plots are tested against theories introduced earlier, namely the relation between the configuration of plots and the concentration and diversity of economic activities in cities (Bobkova et al., 2019b; Marcus and Bobkova, 2019). This is what Scheer (2016) broadly refers to as 'exploring non-formal linkages' and what we call 'testing theories'. The methodology of this step is summarised in Section 5.5 (Step 4).

As noted above, the study of theories of change is beyond the scope of this thesis but is an important direction for future studies and will be discussed further in Section 7 (Discussion).

A summary of the research design steps is presented in Figure 5.1 and the following subsections give a detailed description of the methodology and technicalities behind each step of the thesis.

5. 2 **Step 1. From data to a representation**

In order to proceed to any kind of spatial or quantitative analysis, we first need to develop a consistent methodology for the selection and processing of data to represent plot systems in a GIS-based model of plots. According to Batty (2009), models are "simplifications of reality, theoretical abstractions that represent systems in such a way that essential features crucial to the theory and its application are identified and highlighted". Following the theory of natural occupation, the attributes of plot systems of interest to us are defined as 'land used for long-term occupational uses'. In other words, all types of land not related to movement and thus suitable for any kind of occupation, no matter which kind of land use or type of ownership is administratively assigned to this land.

GIS-layers of plot systems are developed for the five European

11. *Urban morphological zones (UMZ) are defined by Corine land cover classes considered to contribute to the urban tissue and function. A UMZ can be defined as "a set of urban areas laying less than 200m apart" (source: http://www.eea.europa.eu/data-and-maps/data/urban-morphological-zones-2006 (download date 13-7-2016).*

12. *Freehold property data is similar to cadastral data, in that it corresponds to property ownership*

13. *Data sources: Fastighet maps from the Land registry for Sweden, the DKK database for Amsterdam and the Land Registry Inspire Index polygons for London.*

14. *For the data sources of additional spatial layers used for data editing see Atlas of Plots.*

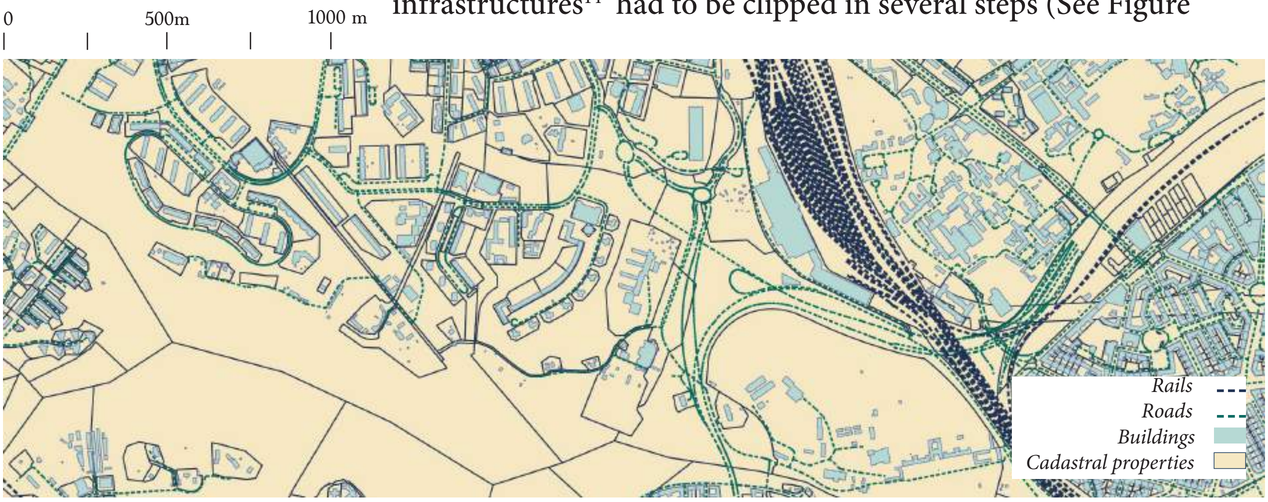
cities, as introduced in Section 1.4: London, Amsterdam, Stockholm, Gothenburg and Eskilstuna.

The study areas include the whole urbanised part of the cities, spanning out from their municipal borders. To ensure comparability in the definition of study areas, we used the Urban Morphological Zone (UMZ) boundaries, as defined by the European Environment Agency (EEA) and the Eurostat for all European cities[11]. However, due to the highly irregular boundaries of the UMZs, which could pose a problem for syntactical analysis of the networks, the convex hull of each UMZ was used instead as a boundary for each study area.

The original datasets on the plot systems were downloaded from the official authorities of each country. The original plot descriptions are based on cadastral data for Amsterdam in the Netherlands and the three Swedish cities and on freehold property data[12] for London[13]. However, cadastral properties and, to a certain extent, freehold property cover all sorts of land, including water and infrastructures (See example on the Figure 5.2). Therefore, the plot systems of interest to this study (all plots not covered by water or movement networks) had to be extracted. This is not unproblematic, as it is quite common for the same cadastral property to cover, say, a built area and the road or water body attached to it.

Therefore, water bodies, roads (motorised networks) and rail infrastructures[14] had to be clipped in several steps (See Figure

FIG. 5.2 Example from Stockholm illustrating how one cadastral property can cover both space for buildings and road/rail infrastructures.



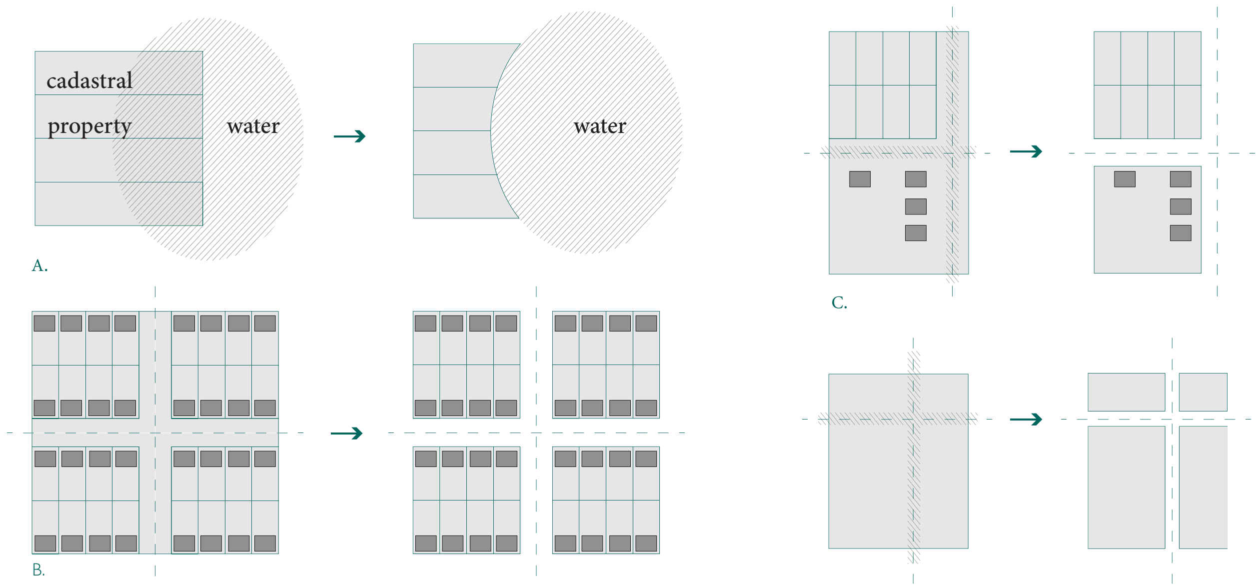


FIG. 5.3 Extraction method of plot layers. A. Clipping bodies of water. B. Removing plots that contain only road networks. C. Clipping roads using a buffer, where the plot includes both road and built area. D. Clipping roads, where they intersect with large single plots (fields and forests, for example).

15. The issue behind clipping water and infrastructure, is that a clipping process creates 'leftover' polygons, especially in the case of clipping infrastructure using a spatial buffer. The size of the spatial buffer (10m) has been chosen iteratively, based on the idea that the final layer of plot systems should preferably have the fewest possible 'leftover' polygons, but at the same time, lose as few polygons as possible from the occupational layer. In some cases, additional buffering was required, where road infrastructure was generally thicker than 20m. In Amsterdam, for example, the size of buffer was increased due to the presence of canals.

5.3 and Atlas of Plots). This clipping also involved creating a 10m buffer from the centrelines of roads and railway lines[15] .

Importantly, to clip infrastructures (road network), the motorized road network[16] was used, that includes all streets accessible by car (including highways) and does not include paths only accessible for pedestrians: for example, paths in the parks or in post-war neighbourhoods. The reason behind choosing the motorized road network instead of the non-motorized (i.e. pedestrian) one is as follows. As discussed above, in every city there are many cadastral properties (i.e. plots) that may cover both built form and street space, and the latter was chosen to be clipped because it does not correspond to occupational space. Clipping pedestrian road network would result in a layer of plots of much finer grain and would differ to a much larger extent from the original layer of cadastral properties.

As a result of this clipping, very small polygons were created that can be deemed 'noise'. These polygons were removed using a city-specific threshold. For example, in Stockholm, all polygons smaller than 40m^2 represented 'noise' and were removed. However, in Amsterdam and London, plots of 20-40m^2 can actually be found, so in this case polygons smaller than 20m^2 were deemed noise and

16. The motorised networks are based on the national road database of each country; the NVDB (Nationell Vägdatabas) for Sweden, the NWB (Nationaal Wegenbestand) for the Netherlands and the OS MasterMap ITN (Integrated Transport Network) for the UK. All roads are represented with one line irrespectively of the number of lanes, except from Motorways and Highways which are represented with two lines, one for each direction, again irrespectively of the number of lanes.

thus removed. Finally, some manual checks were done to remove larger, but clearly leftover, polygons. These included very narrow and long polygons along a water body.

The flow-chart of data management procedure and the resulting GIS-layer of plots are presented in the Atlas of Plots.

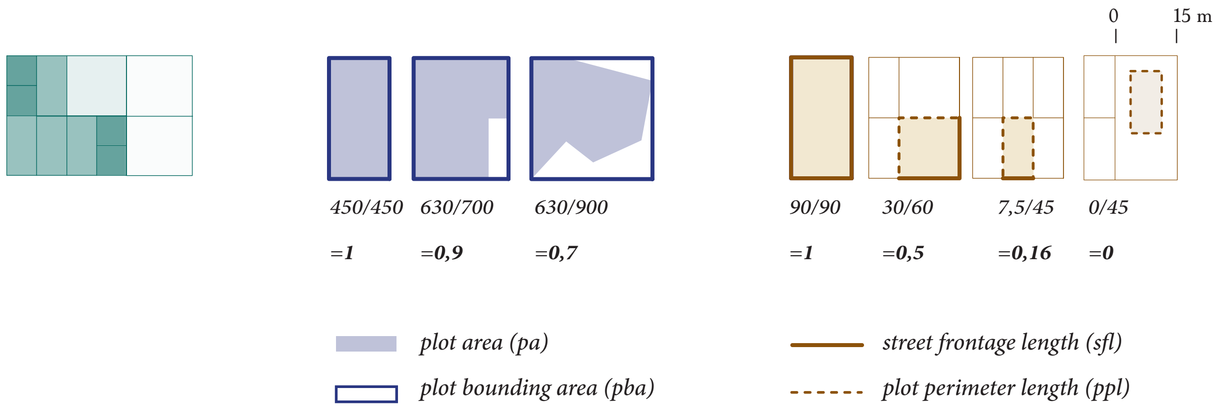
5. 3 **Step 2. Morphological measures of plots.**

5.3.1. Criteria for defining morphological measures

In order to find and define the relevant morphological measures of plot systems, an extensive literature review of urban morphological concepts was conducted (Bobkova et al., 2017b, 2017a), as summarised in Section 3.

Based on the same literature review, also discussed extensively in Section 4, three plot measures were selected to describe plots and plot systems. One was directly reused (plot size and accessible number of plots) while the two others were modified to better fit the purpose of this thesis. For example, in order to measure the divisibility of plots, the most compact shape was considered to be the one closest to a rectangle and not a circle (the measure most often used). The latter can be said to be a mathematical description, while the former is a morphological one and thus more relevant in our case. Besides capturing the three underpinning concepts, as presented in Section 4, the measures had to fulfil two more criteria: applicability and simplicity. Firstly, they should be applicable to the scale of the full city region and be able to describe all kinds of plots. Not just rectangular but also randomly shaped, as is common in, say, post-war areas or natural landscapes. Secondly, we aimed to develop the smallest number of measures capable of capturing the targeted aspects in the most economical way (the Occam's razor principle).

The geometric measures are: plot size (PS), plot compactness index



Plot size *=*
plot area (pa)

Compactness Index *=*
plot area (pa)/
plot bounding area (pba)

Frontage Index *=*
street frontage length(sfl)/
plot perimeter length (ppl)

(PCI) and plot frontage index (PFI) and are calculated using the following equations:

5.3.2. Calculation of accessibility measures

The geometric measures are then translated into accessibility measures, because the general interest here is describing characteristic patterns in cities and not individual plots, as discussed in Section 4.2.

Following the work of Berghauser Pont and Marcus (2014), plot accessibility measures are calculated using the cumulative-opportunities accessibility measure [17] (Bhat et al., 2000) with the distance threshold set at 500m walking distance. The chosen unit of measurement is a 500m radius, which is commonly recognised as the approximate distance that most people are willing to walk (Gehl, 2010). PST (Place Syntax Tool)[18] was used for these analyses. It combines the Space Syntax description of the urban environment

17. See Atlas of Plots

18. PST is a plugin software to QGIS; Software and documentation is available at https://www.smog.chalmers.se/pst.

Accessible number of plots
*AP (o;D) =AR (o;pc;D)**

pc = plot count

Accessible plot compactness index
*APC (o;D) = AR (o;pa;D)/ AR (o;pba;D)**

pa = plot area
pba = plot bounding area

Accessible plot frontage index
*APF (o;D) = AR (o;sfl;D)/ AR (o;ppl;D)**

sfl = street frontage length
ppl = plot perimeter length

**For all three measures:*
AR = attraction reach
o = origin
D = 500m distance threshold

with conventional descriptions of attraction. The equations for the accessible number of plots (AP), accessible plot compactness (APC) and accessible plot frontage (APF) are as follows:

With these six measures (three geometric measures and three complementary accessibility ones), the spatial analysis in the five cities was conducted. This allowed early visualisation of differences between various urban landscapes, based on the distribution of the six measures.

These results are discussed in Section 6 and the Atlas of Plots, including the descriptive statistics of each measure in each city. This allows the quantitative profiles of cities to be described in terms of their plot structure.

5. 4 **Step 3. From measures to analytical types**

As discussed in Section 3.2, types are a powerful way to describe complex patterns. In this thesis, we use unsupervised statistical clustering to develop plot types. The input variables for classification are the three accessibility measures of plots discussed in Section 5.3. These were developed deductively based on urban morphological theories. Cluster analysis was used to make these classifications. This is a common statistical data analysis technique that groups observations in groups in such a way, that observations in one group are more similar to each other, than to observations in other groups.

The steps for this clustering have been discussed extensively in

DATA SOURCES	STEPS	DESCRIPTION
Fastighet maps from Swedish Land registry, downloaded in 2016 www.lantmateriet.se DKK database in Amsterdam, downloaded in 2016 Land registry Inspire Index polygons in the UK	1. Edit map	A. Exclude infrastructure (road and rail) and water including some clipping and correct errors
	2. Spatial analysis	B. Differentiation (Aplot, count); 500m radius Frontage (AFplot, index); 500m radius Compactness (ACplot, index); 500m radius
	3. Statistical analysis	C. Standardise data: equal number of observations from each city combined in one model. Standartize variables: rescaling of Aplot D. Unsupervised K-means clustering (full model) E. Choosing oprimal number of clusters: scree plot, silhouette analysis (one percent of observations in the model) F. Model validation: cross-validating the model to check seven-cluster solution for stability of cluster centroids G. Classification of complete dataset of five cities with predefined cluster centroids

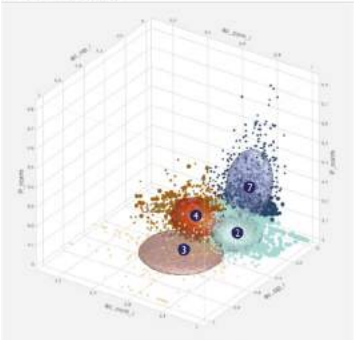
FIG. 5.4 Methodology for extracting plot types

Paper 3 (Bobkova et al., 2019a) and are summarised in Figure 5.4 and below.

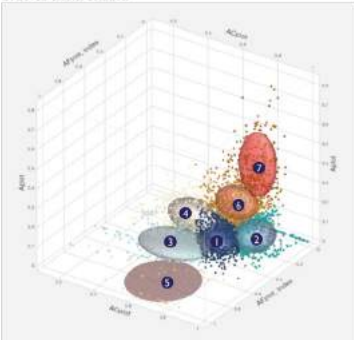
Firstly, samples of equal numbers of observations for each city were extracted. This step is important because the five cities vary greatly in size, which can significantly influence the cluster analysis.

Secondly, k-means cluster analysis was used to classify plots into plot typologies using the three accessibility measures as input variables. K-means cluster analysis is a partitioning process that groups objects in k clusters using the minimum mean distance of the data points to the clusters' centre (Gil et al., 2012). In order to define the optimal number of clusters (k) or types, 19 cluster solutions (from 2 to 20 clusters) were produced and evaluated based on a silhouette analysis (see Paper 3, Sections 3 and 4). Silhouette analysis (Kim, 2009) allows comparison of what are termed 'average silhouette values' for each cluster solution. The highest average values demonstrate that observations in these cluster solutions are comparatively better clustered (ibid.)

A. Four-cluster solution



B. Seven-cluster solution



C. Nine-cluster solution

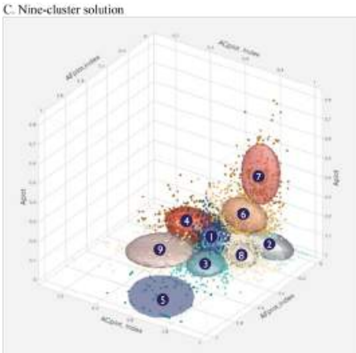


FIG. 5.5 Comparison of cluster solutions in 3D variable space (from top to the bottom): four, seven and nine-cluster solutions

It is important to mention that choosing the optimal number of clusters is not easy and often depends on the particular research question. Interpreting the results also involves expert knowledge. It may also involve a variety of different methods, such as the above-mentioned silhouette analysis, hierarchical clustering, or scree plot. In our case, the silhouette analysis demonstrated the most intelligible results and was further complemented by a visual analysis of 3D scatterplots (Figure 5.5).

Based on the silhouette analyses, scatterplots and comparison of cluster centroids for the solutions with 4, 7 and 9 clusters (Figure 5.5), a final decision was made in favour of the seven-cluster solution.

The seven-cluster solution was checked using model cross-validation to ensure the stability of cluster centres and, finally, the resulting cluster centres were assigned to the whole dataset.

The resulting seven plot types, including how they describe patterns in five cities is discussed extensively in Paper 3 and summarised further in Section 6 and the Atlas of Plots.

5. 5 **Step 4a. Testing theories: correlation between plot types and concentration of economic activities**

After the quantitative descriptions of plot systems using spatial measures and plot types, the theory of natural occupation (as summarised in Sections 2 and 3 and introduced in Papers 1 and 2 (Bobkova et al., 2017a, 2017b)) is tested.

Our ultimate aim is to test the role of plot systems in urban diversity; referred to in Paper 4 (Bobkova et al., 2019b) as 'economic specialisation in cities'. As explained in this paper, one can distinguish two aspects of economic specialisation. Firstly, the greater number of activities due to the division of labour, and secondly, their greater diversity. Paper 4 addresses this first aspect (the number of activities) and answers the question, 'is there a relation between the structure and shape of plot systems in cities and the number of economic activities (in other words, their concentration)?' (ibid.) Paper 5 (Marcus and Bobkova, 2019) addresses the methodology behind the second aspect (the diversity of activities). The methods used will be discussed in Section 5.6.

The guiding hypothesis in Paper 4 is based on Webster and Lai's concept of economic specialisation in cities (Webster and Lai, 2003), arguing that plots of smaller size, more regular shape and smaller frontage generally correspond to higher concentrations of economic activities in cities (see also Section 2).

For this purpose, statistical analysis of co-variation[19] was used. This allows the relation between plot shape and structure and the concentration of these activities to be quantified in three European capital cities (London, Amsterdam, Stockholm[20]). The methodology is summarised below.

Firstly, the dependent variable of the economic activities'

19. Statistical analysis is processed in SPSS software.

20. The study was narrowed down to three cities instead of five because, according to preliminary tests, the differences between Swedish cities were not that critical compared to Amsterdam and London. Also, we were mainly interested in cross-cultural comparison, not in the performance of Swedish cities in particular.

FIG. 5.6 Concentration of economic activity within selected observations (plots).

concentration was measured as the sum of economic activities per plot area. This is, in other words, the sum of economic activity (the count) within each plot divided by the plot area[21]. In order to control for land-use regulations, plots that did not have any economic activities were excluded from the analysis (See the model of economic activity on Figure 5.6). The independent variables were the seven plot types, generated as described above (Section 5.4).

Thirdly, statistical models were constructed in which we controlled for other spatial variables that are generally recognised as influencing the distribution of activities in cities; street centrality and built density[22] .

Finally, to understand whether there are any statistical differences between the plot types, in terms of the dependent variable distribution, a statistical analysis was conducted using the Kruskal-Wallis H test. This test is commonly used as a non-parametric alternative to a one-way ANOVA analysis when the data fails the assumptions required for ANOVA (normality of dependent variable distribution, lack of outliers and equal variance within each plot type) (Bobkova et al., 2019b).

21. The model of economic activity was based on point data taken from Open Street Map (points of interest) and included the concentration of retail and food services. For the clarifications see Paper 4 (Bobkova et al., 2019).

22. To control for built density and street centrality we used built and street types developed within the Spatial Morphology Lab research project (Berghauser Pont et al., 2019, 2017, in press; Berghauser Pont and Olsson, 2017). For clarifications, see Paper 4 (Bobkova et al., 2019b).

5. 6 **Step 4b. Testing theories: correlation between plot accessibility and diversity of economic activity**

Next study was conducted to test the second aspect of economic specialisation, diversity of activities. This is presented in Paper 5.

The twofold aim of Paper 5 (Marcus & Bobkova, 2019) was, firstly, to present an overview of the complex issues behind the diversity concept, focusing on categorisation and scale and, secondly, to conduct empirical testing of the hypothesised impact of plot systems on diversity of activities. The particular focus of Paper 5 was not to test all the measures introduced in the thesis; just the measure relating directly to the spatial capacity concept (or plot differentiation) as described in Section 3.2 (‘plots in space’). Hence, instead of plot types (used in Paper 4 as an explanatory variable), the only measure used was for accessible number of plots.

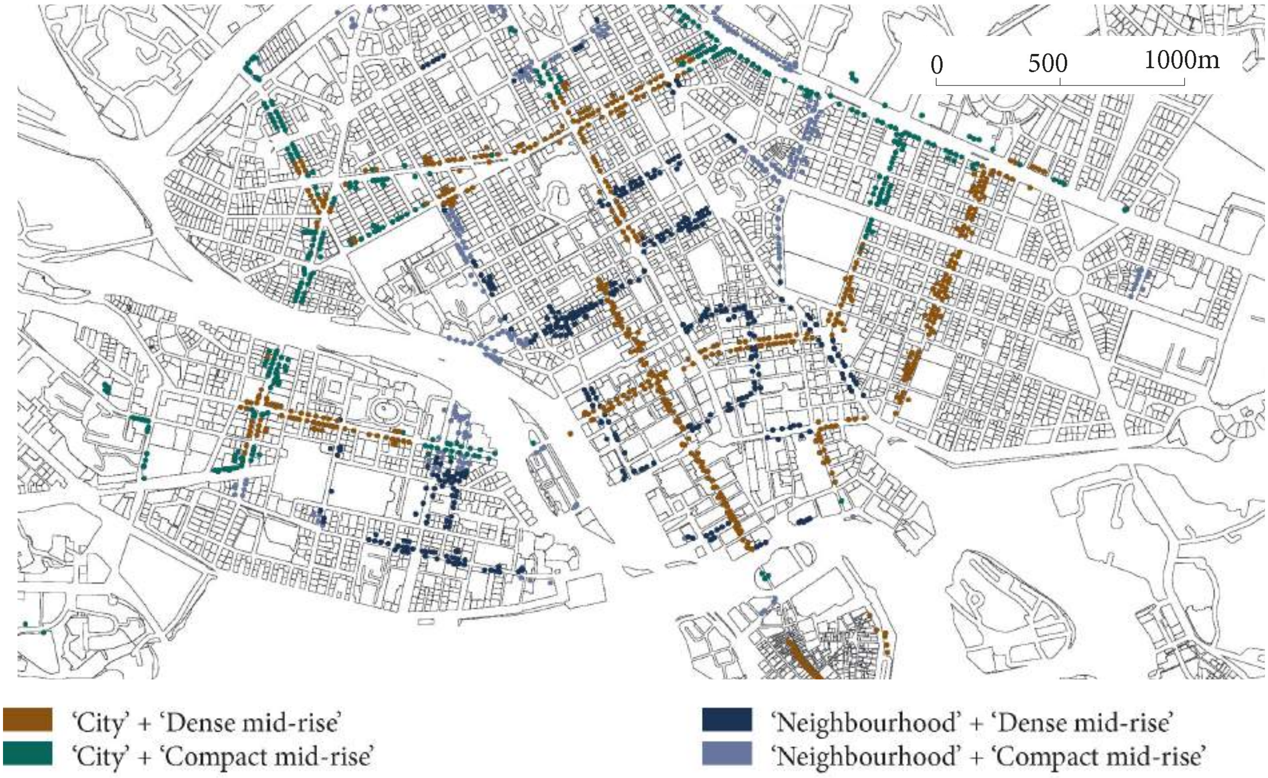


FIG. 5.7 Four sub-models allowing to control for building density and street centrality

The first part of Paper 5 describes the complex theoretical and methodological issues behind measuring urban diversity, building further on the work of Sayyar and Marcus (2013) and Paper 1 (Bobkova et al., 2017a). In the second part, a diversity measure is introduced that may potentially capture aspects of categorisation and scale. The methodology of analysis is then discussed, which is rather similar to Paper 4 in that a statistical analysis of co-variation is conducted and variables of street centrality and built density are controlled.

The differences from the previously described method are as follows:

Firstly, only one case study, Stockholm, has been chosen instead of three cities[23] . Secondly, the performance of plots was analysed within several density and street types in combination, as introduced by Berghauser Pont et al. (Berghauser Pont et al., 2019). Two building types with the highest built density ('Dense mid-rise' and 'Compact mid-rise') and two street centrality types ('City' and 'Neighbourhood') with the highest betweenness centrality across

23. This study was partly explorative and aimed first to test the diversity measures using different kinds of categorisations and spatial scales; hence it was narrowed down to just one city. In the next steps, the study could also be extended to cross-cultural comparisons, adding Amsterdam and London.

different scales were selected, thus forming four sub-models (Figure 5.7)

When it comes to capturing dependent and independent variables, our interest was in capturing different urban scales for both. Hence, both dependent and independent variables were measured across several scales: three scales (500m, 1000m and 2500m) for the independent variable of accessible number of plots and two for the dependent variable of diversity[24] . The technicalities behind measuring the variable of diversity are explained below.

24. Ideally, one would be interested to capture diversity also at three levels, but we here were limited by data (OSM, points of interest), that allows only two kinds of categorisation

Diversity is measured using the Simpson Diversity Index, a generally recognised indicator for measuring the diversity of urban activities (Talen, 2008). However, diversity in economic activity can be found at different urban scales. Hence, the central question, besides 'diversity of what?', is 'diversity on what urban scale?' This was addressed by introducing two kinds of diversity: 1) general diversity (referred to subsequently as $D_{general}$) that includes all kinds of basic urban services more evenly distributed across the city (excluding offices) and 2) retail diversity (referred subsequently as D_{retail}), that usually associated with the intensity of pedestrian-related economic activities in lively city centres (Scoppa and Peponis, 2015). Both indices ($D_{general}$ and D_{retail}) are calculated and measured as accessibility within a 500m radius. Accessibility to each separate category was calculated first, followed by accessibility to the total number of categories. The resulting numbers were then used to calculate the Simpson Diversity Index[25], by the following equation:

25. In the Simpson Diversity Index the bigger the value of D, the lower the diversity. To make it more intuitive the value of D is subtracted from 1, so the values closest to 1 mean higher diversity (1-D)

$$\mathbf{D=\Sigma(An/AN)^2}$$

where **An** is the number of activities within each category accessible within a 500m walking distance, and **AN** is the total number of all activities accessible within a 500m walking distance.

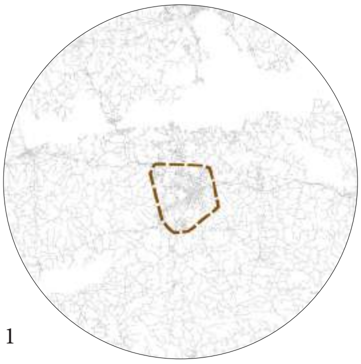
Bivariate Pearson correlations were then run, with accessibility to plots at these three scales correlated to both general and retail diversity. Residual values were mapped to evaluate underpredicted or overpredicted values, indicating that there might be other variables influencing higher or lower diversity in particular areas but not included in our analysis.

Intermission

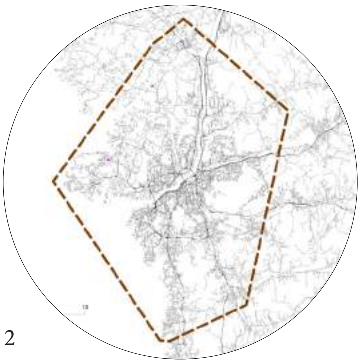
Atlas of plots

Atlas contents:

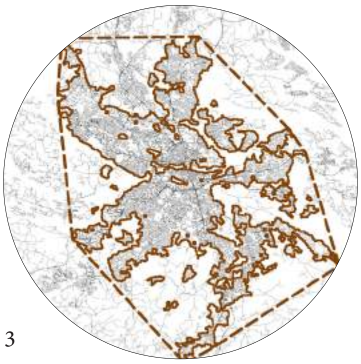
Overview of study areas with convex hulls. 1.Eskilstuna; 2. Gothenburg; 3. Stockholm; 4. Amsterdam; 5. London



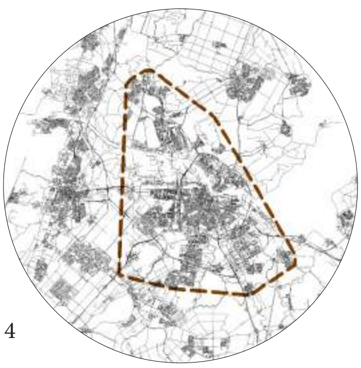
1



2



3



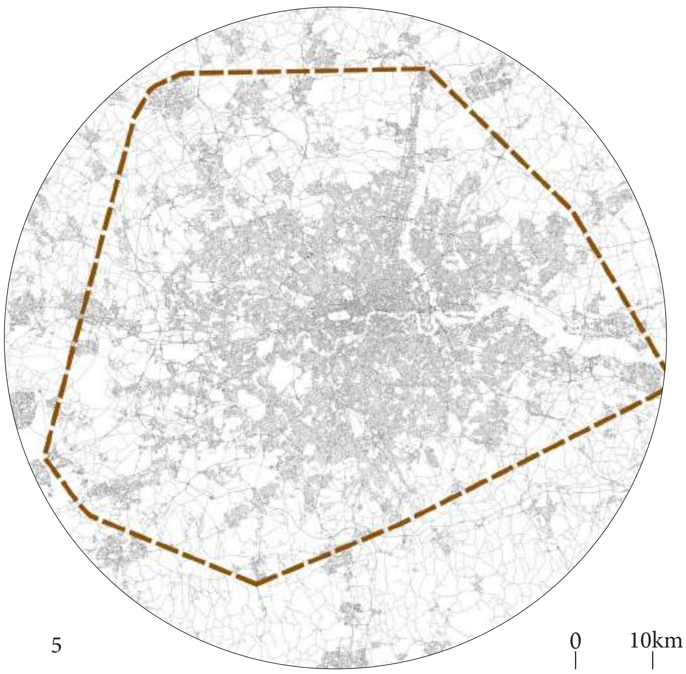
4

From data to a representation

Defining study areas

The study areas include metropolitan areas of the cities, which extend beyond mere municipal borders. For this reason, the Urban Morphological Zone (UMZ) boundaries are used, as defined by the European Environment Agency (EEA).

However, because of the highly irregular boundaries of the UMZs which could become problematic to the syntactical analysis of the networks, what was instead used as the boundary of each study area, was the convex hull of each UMZ.



5

Extracting plots layer from cadastral/freehold properties maps

Following the theory of natural occupation, the attributes of plot systems of interest to us are defined as 'land used for long term occupational uses' or, in other words, all types of land that are not related to movement and thus suitable for occupation of any kind.

The original datasets on the plot systems were downloaded from the official authorities of each country. The original plot descriptions are based on cadastral data for Amsterdam in the Netherlands and the three Swedish cities, and on freehold properties data for London, UK. However, cadastral properties, and to a certain extent freehold properties, cover all sorts of land, including water and infrastructures. Therefore, the plot systems of interest for this study, that is all plots that are not covered by water or movement networks, are extracted. This is not unproblematic because it is rather common that the same cadastral property covers, for instance, built area and the road or water body attached to it.

Therefore, water bodies, roads (motorised network) and rail infrastructures had to be clipped in several steps as shown in the flow chart.

Data sources for plots layer editing

SPATIAL LAYERS	SWEDISH CITIES (STOCKHOLM, GOTHENBURG, ESKILSTUNA)	AMSTERDAM	LONDON
Original layer of cadastral or freehold (in London) properites	Fastighet maps from Swedish Land registry, downloaded in 2016 www.lantmateriet.se	DKK Percelen, database in Amsterdam, downloaded in 2016	Land Registry INSPIRE Index Polygons in London, downloaded in 2016
SUPPORTING LAYERS			
Water	Water layer from Swedish Land registry, downloaded in 2016 (table 'Mv_get') www.lantmateriet.se	TOP10 NL (Waterdeel VLAK), downloaded in 2016	MastermapTOPO (Column 'theme', attribute 'water')
Roads (motorised, segment maps)	Motorised road network, based on the Road-Centre-line maps from the Trafikverket, downloaded in 2016 www.trafikverket.se	Motorised road network, based on the Road-Centre-line maps from Rijkswaterstaat-CIV, downloaded in 2016	Motorised road network, based on the Road-Centre-line maps from the Ordnance Survey, downloaded in 2016
Railways	Railway maps from the Trafikverket, downloaded in 2016 (exclude tunnels, light rails, metro lines and trams) www.trafikverket.se	TOP10 NL (Spoorbaanddeel_Lijn excluding 'buiten gebruik', 'metro', 'tram','sneltram'), downloaded in 2016	MastermapTOPO (Column 'theme', attribute 'rail')
Nature (forests and open fields)	Forests and open fields layer from Swedish Land registry, downloaded in 2016 (table 'Mo_get', excluding attribute 'opmark') www.lantmateriet.se	TOP10 NL	MastermapTOPO
Buildings	Laser dataset, including coordination and elevation values for each point collected from LIDAR (Light Detection and Ranging).		

Data manipulation flowchart

Step 1: clip water, deaggregate multipart polygons into singleparts

Original layer of cadastral properties

Step 2: Overlay with road and rail infrastructure. Put aside plots that do not interesect with any kind of infrastructures

Plots with no water

Plots with no water or infrastructure

Step 3: Clipping rails and roads with fixed buffer 10m (buffer distance has been chosen iteratively, and can be increased/ decreased depending on the context, in order to have the fewest number of 'leftover' polygons)

Plots with no water, but with roads and rails

Resulting layer of occupation

Step 4: Overlay with buildings and large nature areas (forest, fields). Put aside plots that contain any of these

Plots with no water and clipped 10m buffer from the roads and rails

Plots with infrastructure clipped, but interesecting with buildings or large nature areas (make final manual check).

Step 5: Remove smallest leftover polygon (area threshold is chosen for each city iteratively)

Leftover plots

Smallest plots (less than 40 m^2 for Swedish cities, 20 m^2 for Amsterdam and 20 m^2 for London

Leftover plots

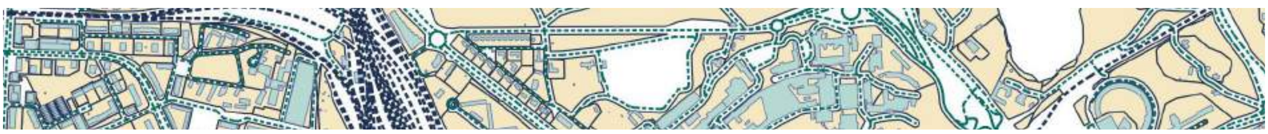
Cadastral/freehold properties (plots data)

Layer of occupation (representation of plot systems)

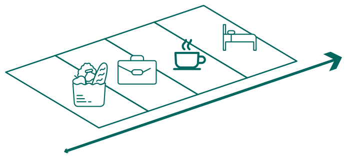
0 1000m 2000 m

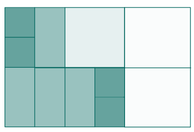
Rails
Roads
Buildings
Plots

0 500m 1000 m



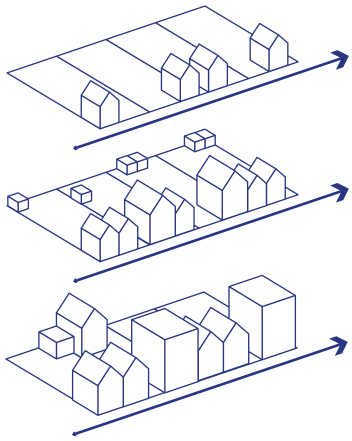
Plots in space

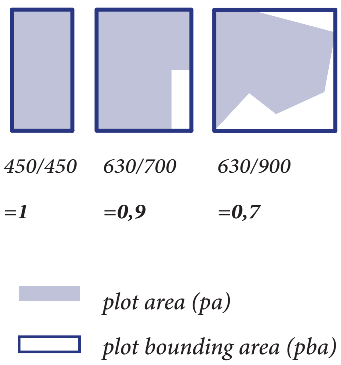




Plot size =
plot area (pa)

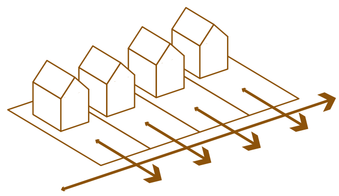
Plots in time

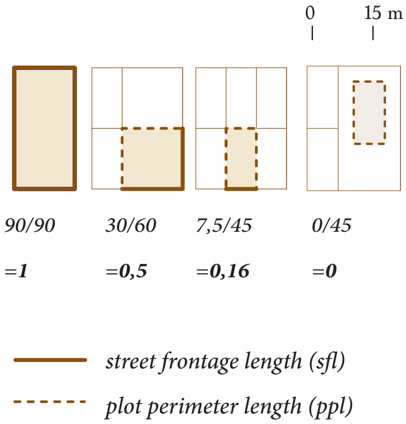




Compactness Index =
plot area (pa)/
plot bounding area (pba)

Plots as an interface





Frontage Index =
street frontage length(sfl)/
plot perimeter length
(ppl)

Geometric measures of plots

From concepts to measures

During literature review, cornerstone concepts that highlight the importance of plots for urban processes in cities have been identified. These concepts are summarised as 'plots in space', 'plots in time' and 'plots as interface'. We see these concepts as supporting for the theory of natural occupation. For each concept, a morphological measure is developed.

'Plot size' measure captures capacity to host diverse owner strategies, or what is referred to as 'plots in space'. It is captured simply as a plot area.

'Plot compactness index' captures the aspect of plots divisibility that is argued to contribute to ability of plot systems to adapt for changes over time be it plot fragmentation or amalgamation. Conceptually this is referred to as 'plots in time'. It is measured as the ratio between plot area and the area of the minimum rectangle bounding that plot.

'Plot frontage index' captures the proportion of plot's street form, and is argued to influnce the degree of interaction with public space, it is, hence, referred to 'plots as interface'. It is measured as the ratio between the plot's street frontage length to its total perimeter.

Descriptive statistics of geometric measures

Descriptive statistics of geomteric measures

	LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA	TOTAL
area (sqkm)	3411	416,5	1084	733	72,5	
total N of observations	3069673	579405	381878	303835	94731	4429522
SIZE						
mean (m^2)	1366	1984	11539	13180	29026	3726
median (m^2)	239	166	1000	1112	1183	267
st dev	18416	15789	127314	78932	168335	52228
variance	339165598	249291448	16209079460	6230375708	28336898790	2727777812
max (m^2)	6667380	4932780	25464700	5351810	10438768	25464700
min (m^2)	20	20	40	**40**	40	20
percentiles 25	145	119	455	555	672	150
50	239	165	1000	1112	1183	267
75	403	391	2207	2865	3452	610
COMPACTNESS INDEX						
mean	0.87	0.87	0.80	0.76	0.78	0.85
median	0.94	0.96	0.85	0.80	0.84	0.93
st dev	0.16	0.19	0.19	0.21	.20	0.17
variance	0.026	0.039	.037	0.043	.041	.031
max	1	1	1	1	1	1
min	0.005	0.004	0	0.005	0.004	0
percentiles 25	0.82	0.82	0.7	0.64	0.66	0.78
50	0.94	0.96	0.85	0.81	0.84	0.93
75	0.98	0.99	0.96	0.93	0.96	0.98
FRONTAGE INDEX						
mean	0.19	0.22	0.27	0.30	0.28	0.21
median	0.11	0.13	0.21	0.25	0.23	0.13
st dev	0.20	0.22	0.23	0.24	0.23	0.21
variance	0.039	0.049	0.051	0.059	0.053	0.044
max	1	1	1	1	1	1
min	0	0	0	0	0	0
percentiles 25	0.08	0.09	0.11	0.11	0.13	0.08
50	0.11	0.13	0.22	0.25	0.23	0.13
75	0.23	0.33	0.43	0.47	0.45	0.29

- *London has approx **4 times** more plots than 3 Swedish cities in total and **5 times** more plots than Amsterdam.*

- *Amsterdam and then London have the smallest plots, that are on average **4-6 times** smaller than plots in Swedish cities.*

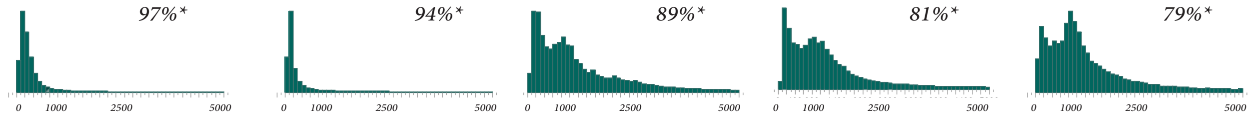
- *Amsterdam and London have the most compact plots (closest in shape to a rectangle) compared to Swedish cities, and plot compactness index of Swedish cities drops from Stockholm to Eskilstuna (the smaller the city is, the less urbanised it is and plots are less compact)*

- *London has plots with the smallest frontages, that are slightly higher in Amsterdam. In Swedish cities street frontages are longer, having the highest frontage index in Gothenburg*

Distributions

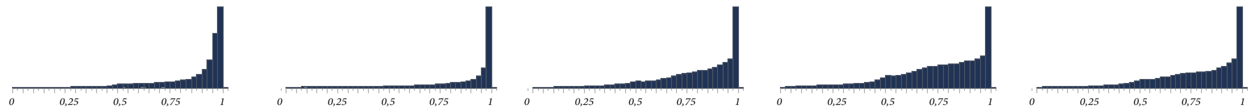
LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA
3411	416,5	1084	733	72,5
3069673	579405	381878	303835	94731

SIZE

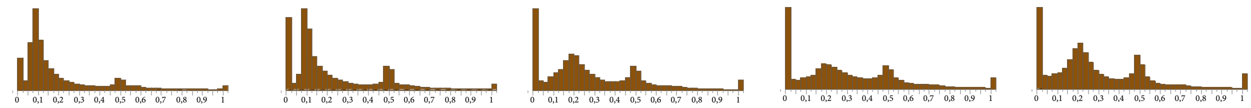


**For plot sizes observations higher than 5000sqm are removed from histograms, in order not to distort data with extra large plots.*
The number on the top shows percentage of observations lower than 5000sqm for each city.

COMPACTNESS INDEX



FRONTAGE INDEX



- *Distributions of plot size demonstrate striking difference between Swedish cities in London and Amsterdam, where the former for instance have a large share of plots of approximately 1000sqm. Over 20% of plots in Swedish cities are larger than 5000sqm, while in London and Amsterdam this share is only 3-6% respectively.*

- *When distribution of compactness index values is assessed, one can see that London and Amsterdam are in general characterised by the most compact plots.*

- *Distributions of frontage index values demonstrate clear 'spikes' close to zero values (those are plots that do not have any access to public space), low values such as 0.1 in Amsterdam in London and 0.2 in Swedish cities (typical row plots in grid-like farbics), as well as average values of 0.5 that clearly distinct corner plots of perimeter blocks. Small kinks at 1, represent open plots that constitute single block i.e. surrounded by streets from all sides.*

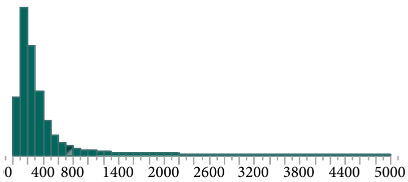
Plot size: London

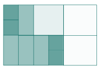
mean (m^2)	*1366*
median (m^2)	*239*
st dev	*18416*
variance	*339165598*
max (m^2)	*6667380*
min (m^2)	*20*

0 0,5 1 2 3 km

0 500 1000 m

small large





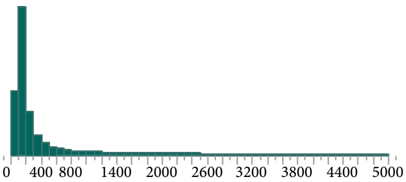
Amsterdam

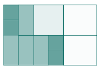
mean (m^2)	*1984*
median (m^2)	*166*
st dev	*15789*
variance	*249291448*
max (m^2)	*4932780*
min (m^2)	*20*

0 0,5 1 2 3 km

0 500 1000 m

small large





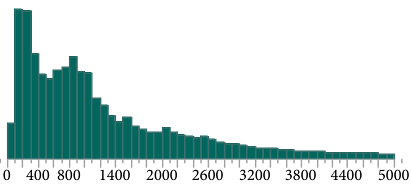
Plot size: Stockholm

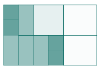
mean (m²)	*11539*
median (m²)	*1000*
st dev	*127314*
variance	*16209079460*
max (m²)	*25464700*
min (m²)	*40*

0 0,5 1 2 3 km

0 500 1000 m

small large





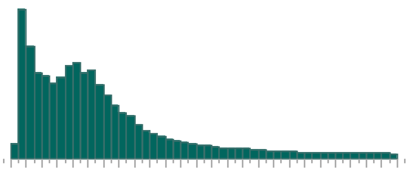
Gothenburg

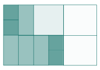
mean (m^2)	*13180*
median (m^2)	*1112*
st dev	*78932*
variance	*6230375708*
max (m^2)	*5351810*
min (m^2)	*40*

0 0,5 1 2 3 km

0 500 1000 m

small large

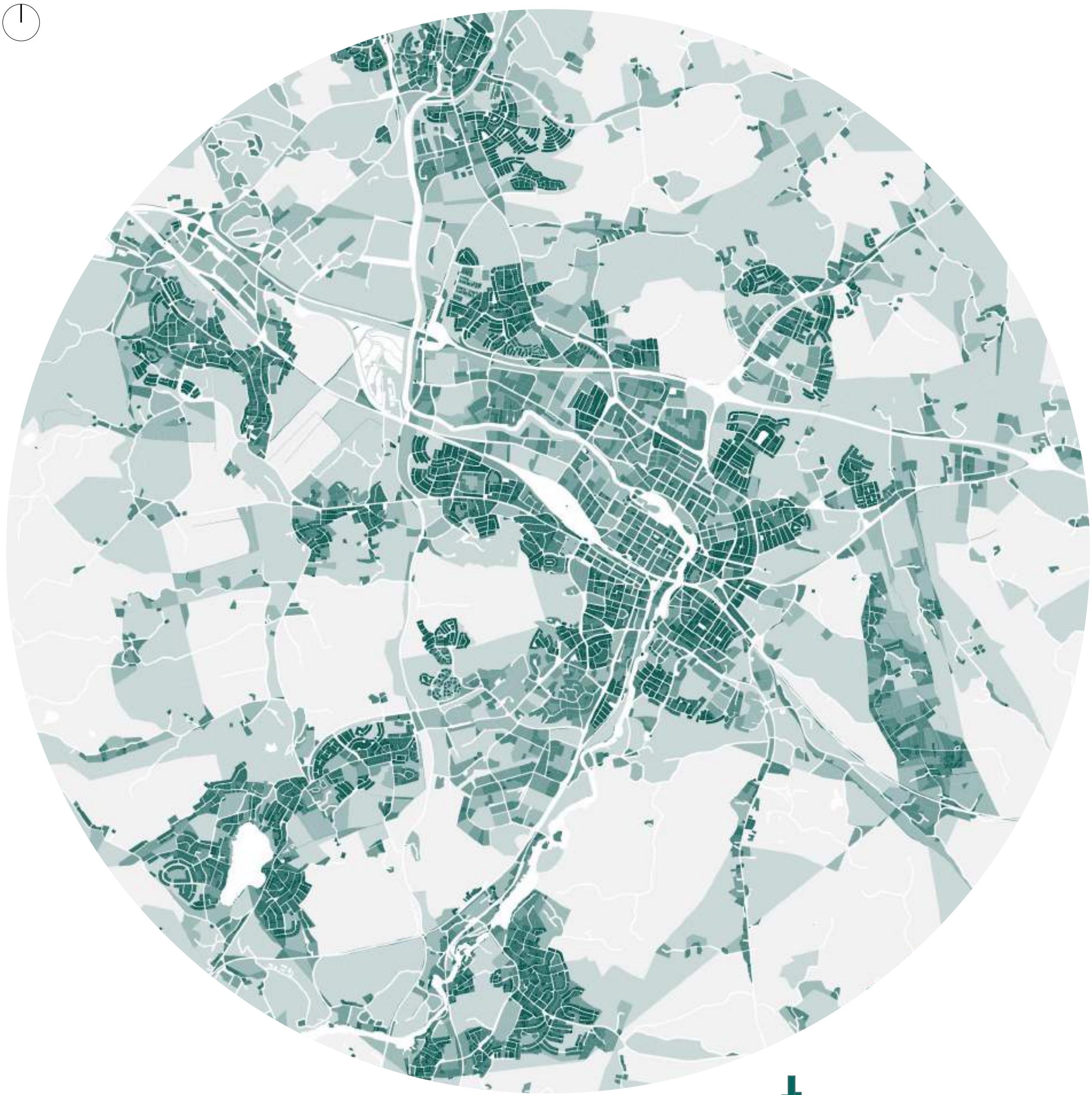




Plot size: Eskilstuna

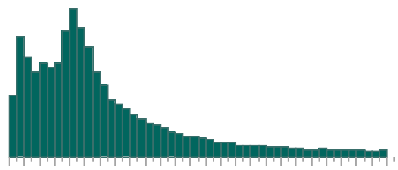
mean (m²)	*29026*
median (m²)	*1183*
st dev	*168335*
variance	*28336898790*
max (m²)	*10438768*
min (m²)	*40*

0 0,5 1 2 3 km



0 500 1000 m

small large



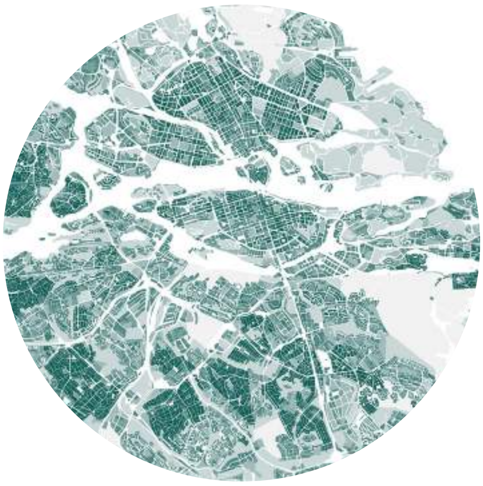
Five cities comparison

0 1 5km

London

Amsterdam

Stockholm



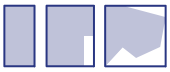
Gothenburg

Eskilstuna

Plots in the three Swedish cities are much larger than plots in Amsterdam and London. In Swedish cities, plots are smaller in the biggest city Stockholm compared to the much smaller city Eskilstuna.

In the non-urbanized areas such as the periphery (most prominent in Eskilstuna) and natural areas within cities plots are bigger.

small  large

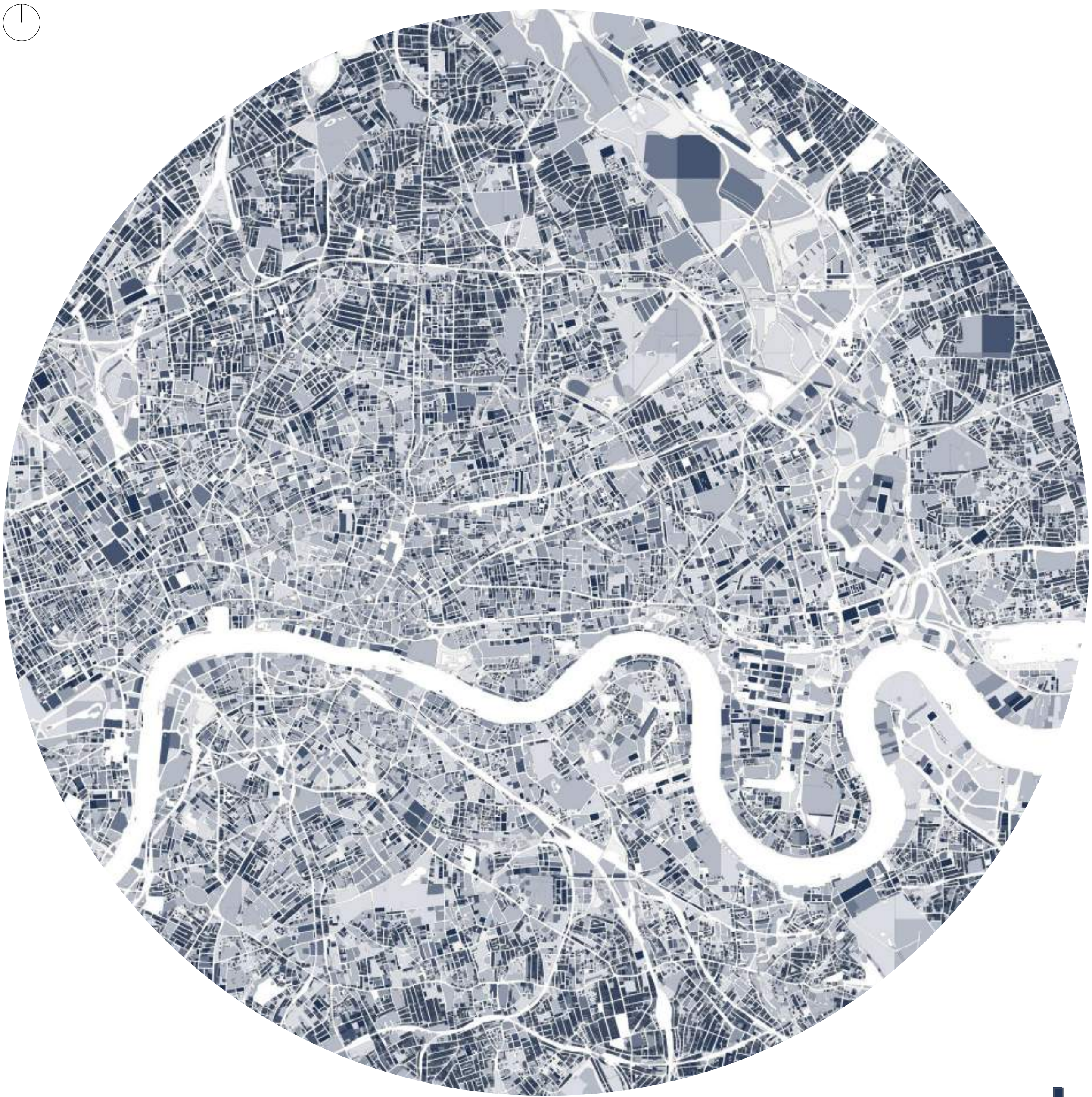


0 0,5 1 2 3 km

Compactness index:

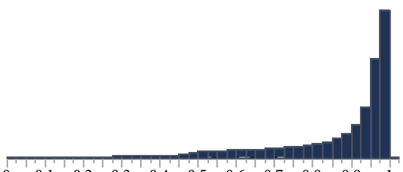
London

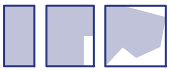
mean	*0.87*
median	*0.94*
st dev	*0.16*
variance	*0.026*
max	*1*
min	*0.005*



0 500 1000 m

0 1





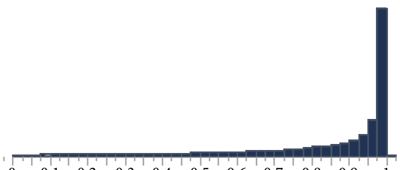
Amsterdam

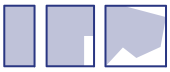
mean	*0.87*
median	*0.96*
st dev	*0.19*
variance	*0.039*
max	*1*
min	*0.004*

0 0,5 1 2 3 km

0 500 1000 m

0 1

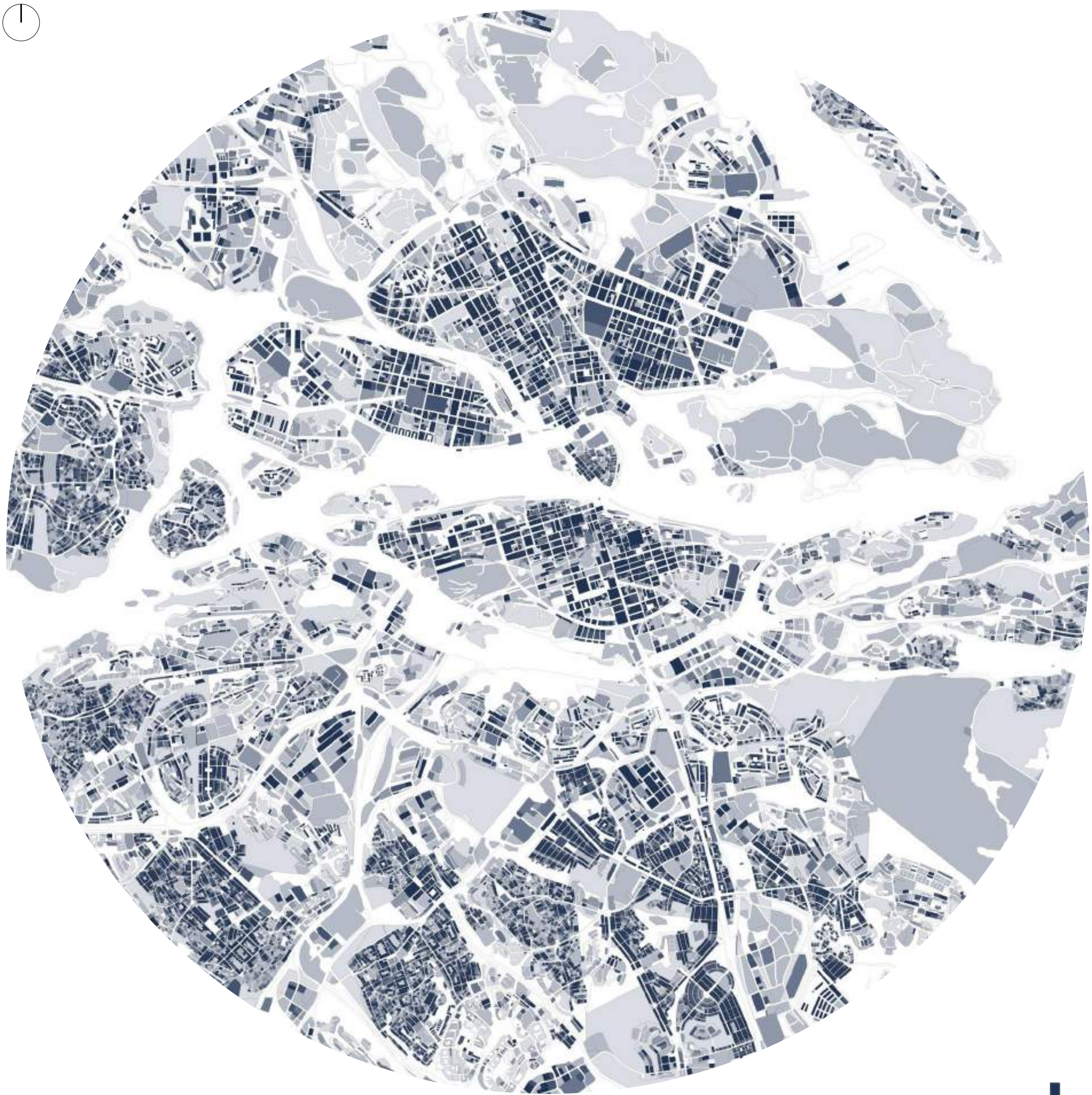




Compactness index: Stockholm

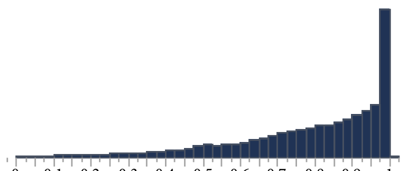
mean	*0.80*
median	*0.85*
st dev	*0.19*
variance	*0.037*
max	*1*
min	*0*

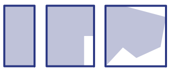
0 0,5 1 2 3 km



0 500 1000 m

0  1

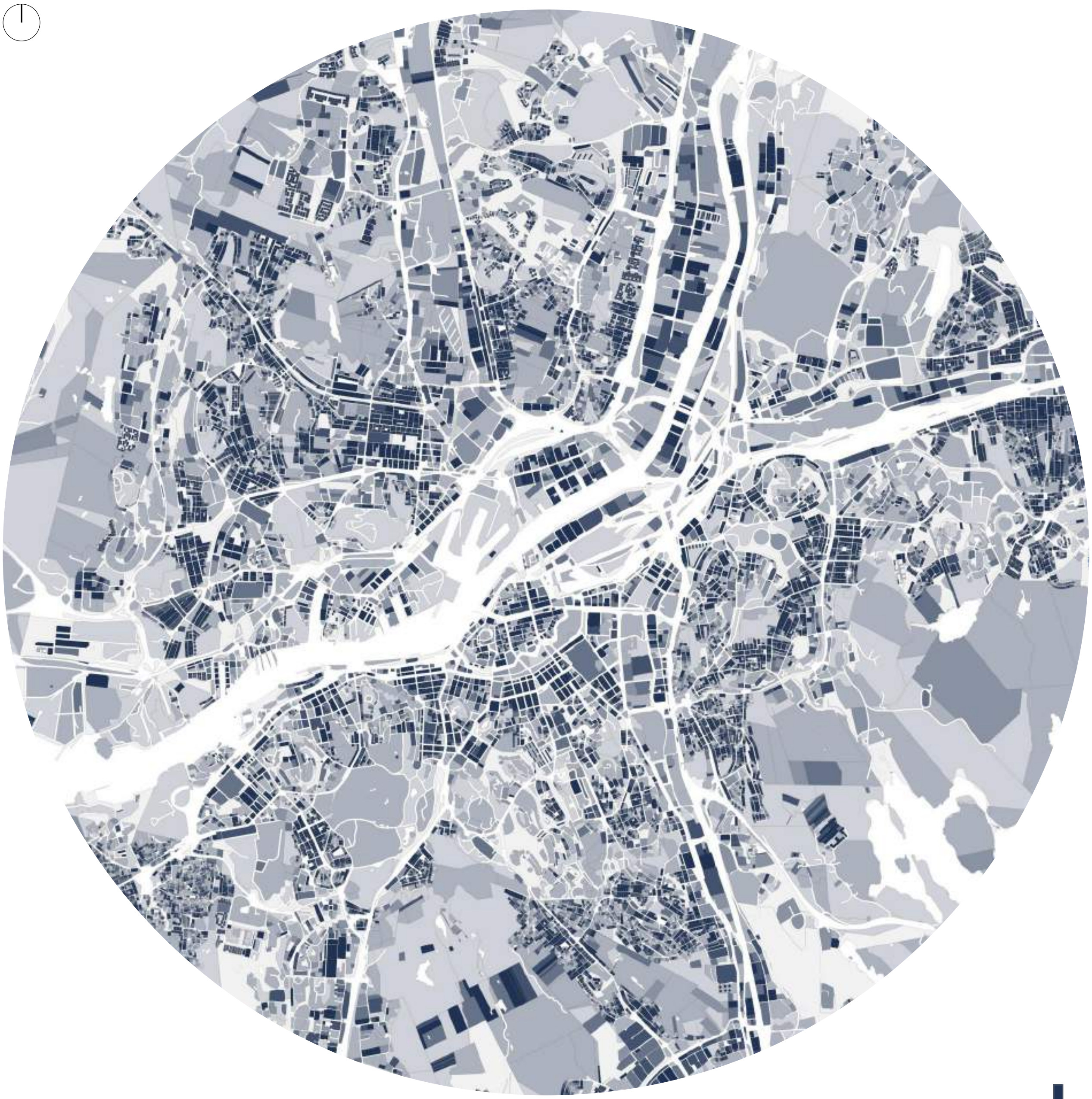




Gothenburg

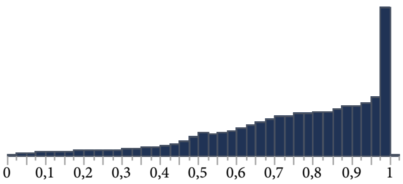
mean	*0.76*
median	*0.80*
st dev	*0.21*
variance	*0.043*
max	*1*
min	*0.005*

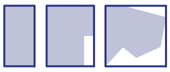
0 0,5 1 2 3 km



0 500 1000 m

0 1



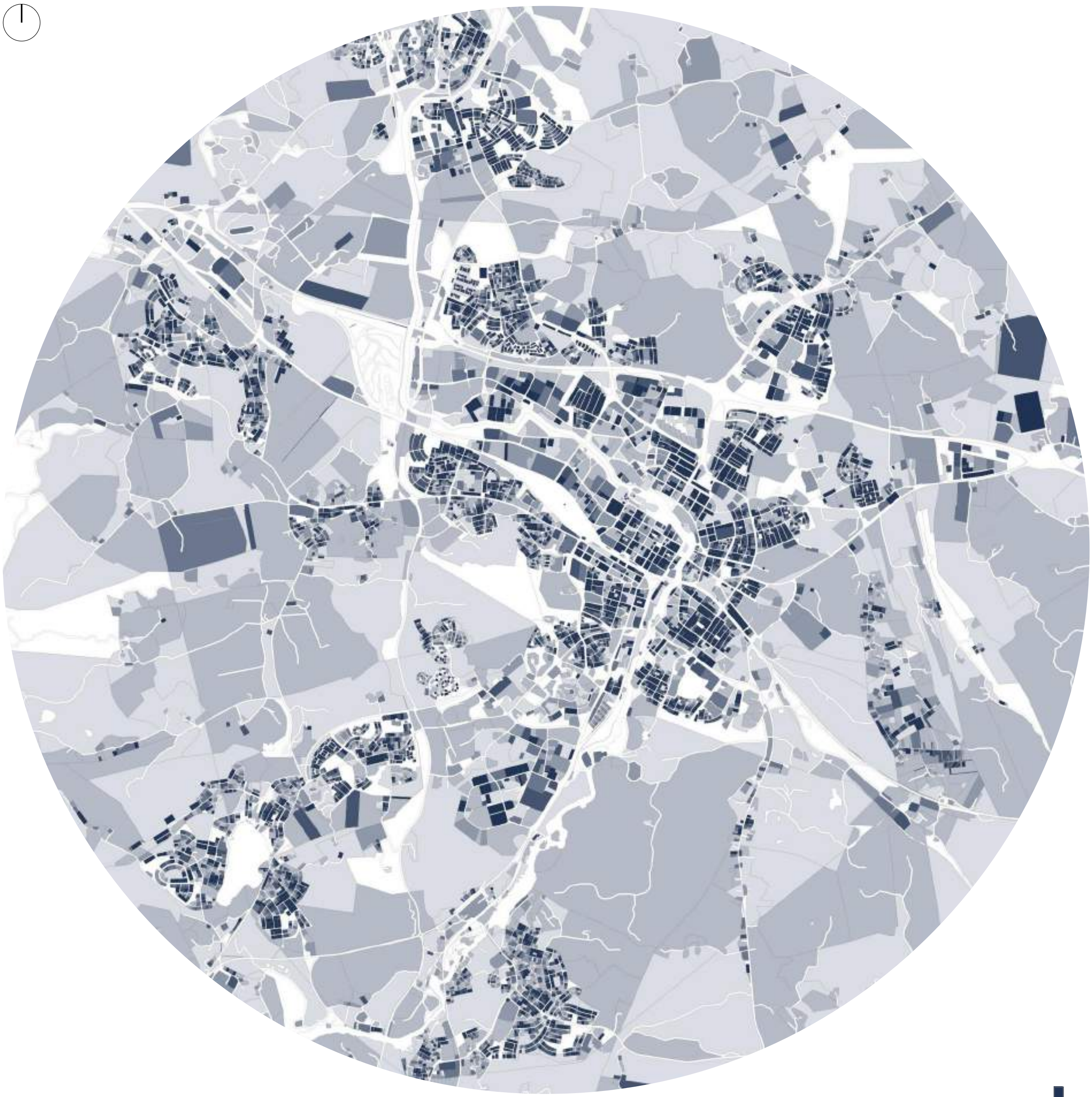


0 0,5 1 2 3 km

Compactness index:

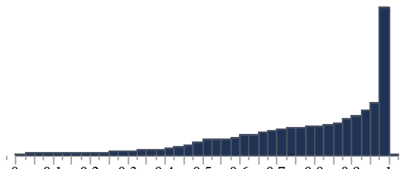
Eskilstuna

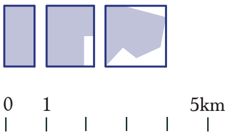
mean	*0.78*
median	*0.84*
st dev	*.20*
variance	*.041*
max	*1*
min	*0.004*



0 500 1000 m

0  1



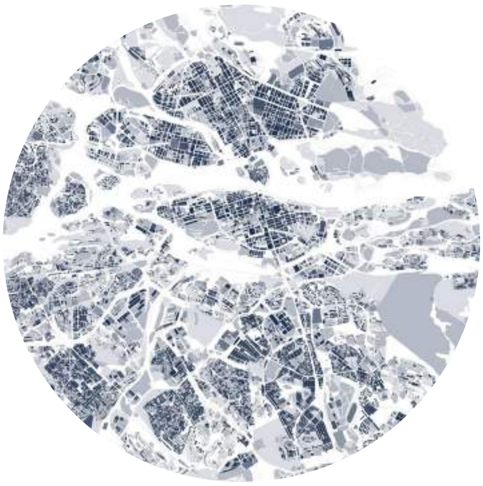


Five cities comparison

London

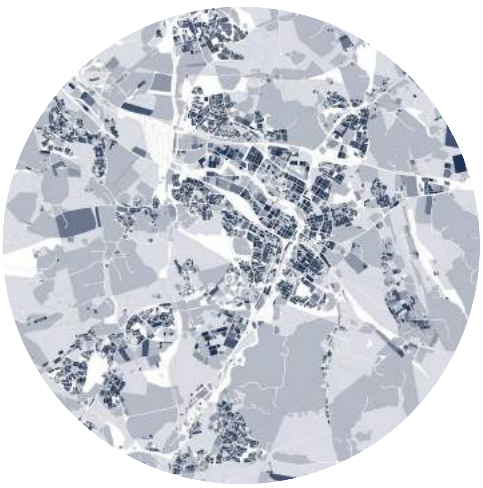
Amsterdam

Stockholm



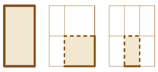
Gothenburg

Eskilstuna



Plot compactness is slightly higher in Amsterdam and London in comparison to the three Swedish cities.

The most compact plots are found in the more urbanised areas, but this can entail both city centre or villa areas.

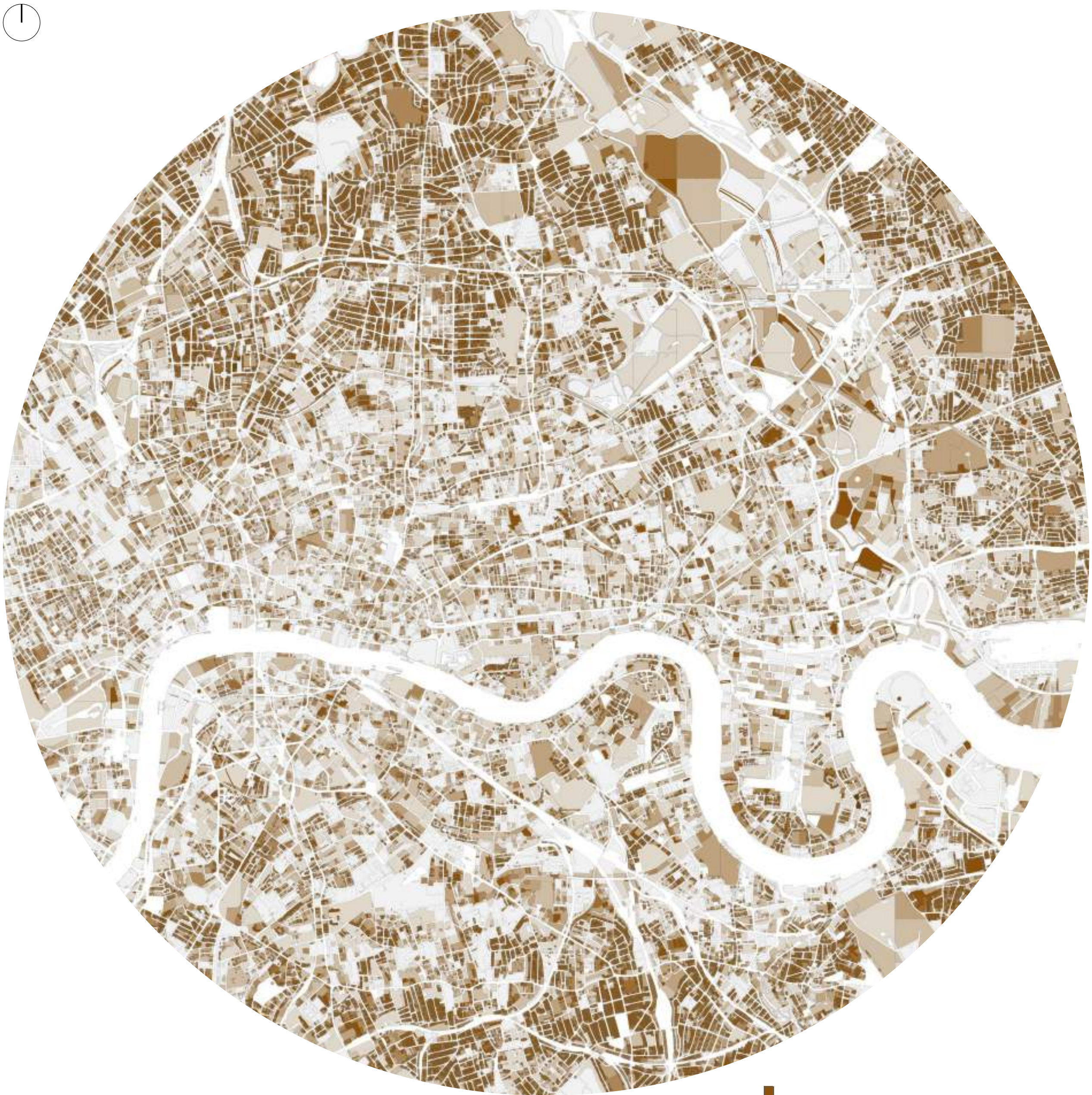


0 0,5 1 2 3 km

Frontage Index:

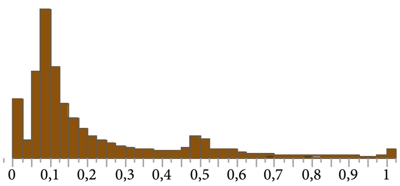
London

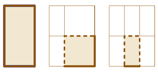
mean	*0.19*
median	*0.11*
st dev	*0.20*
variance	*0.039*
max	*1*
min	*0*



0 500 1000 m

1 0





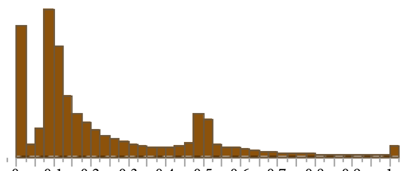
Amsterdam

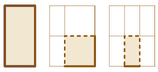
mean	*0.22*
median	*0.13*
st dev	*0.22*
variance	*0.049*
max	*1*
min	*0*

0 0,5 1 2 3 km

0 500 1000 m

1 0

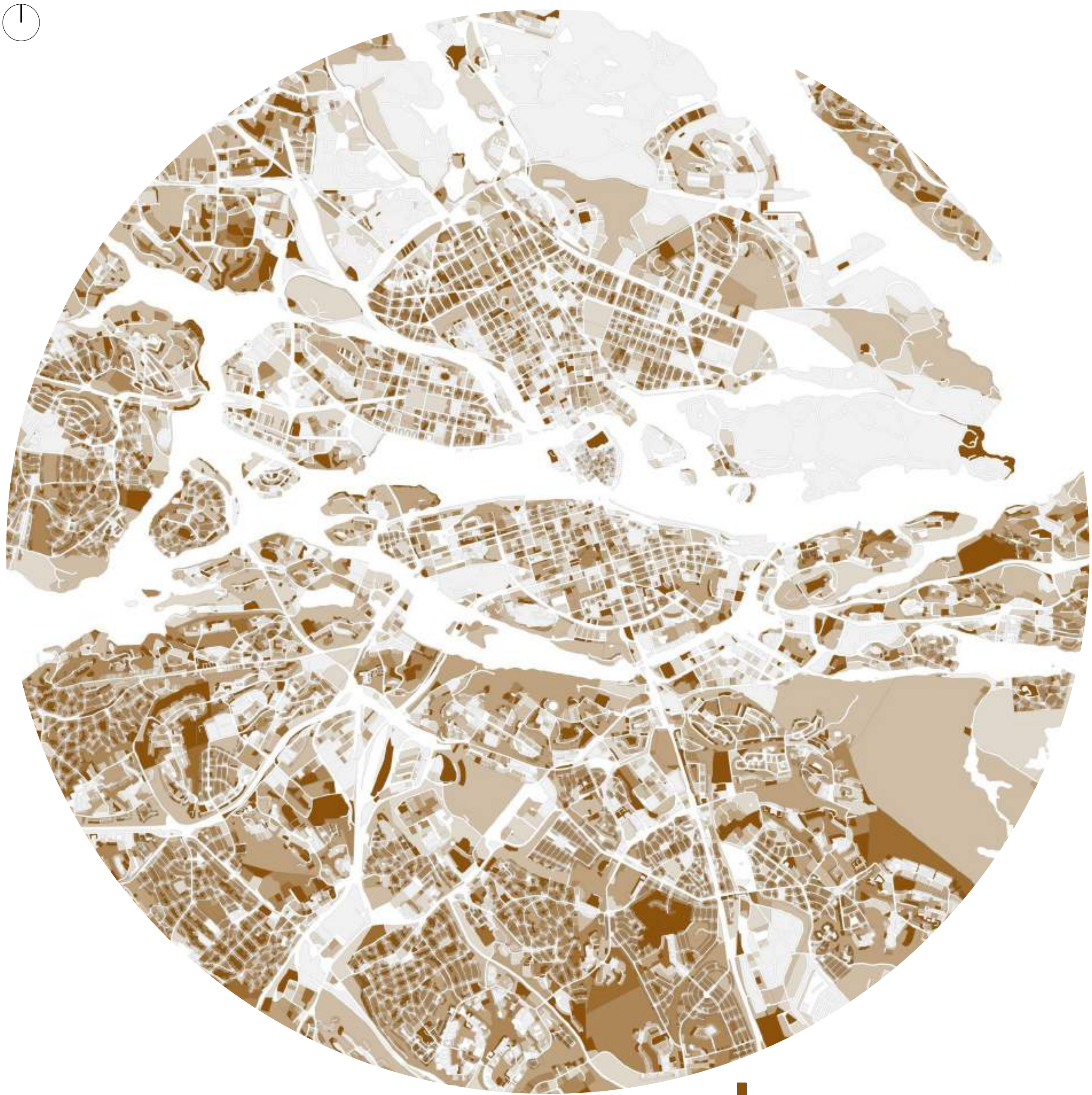


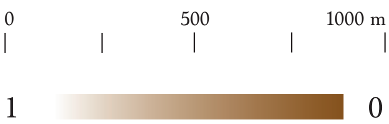


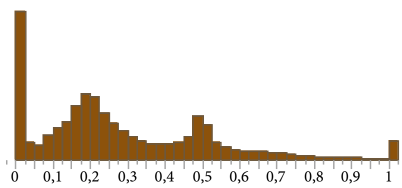
Frontage Index:

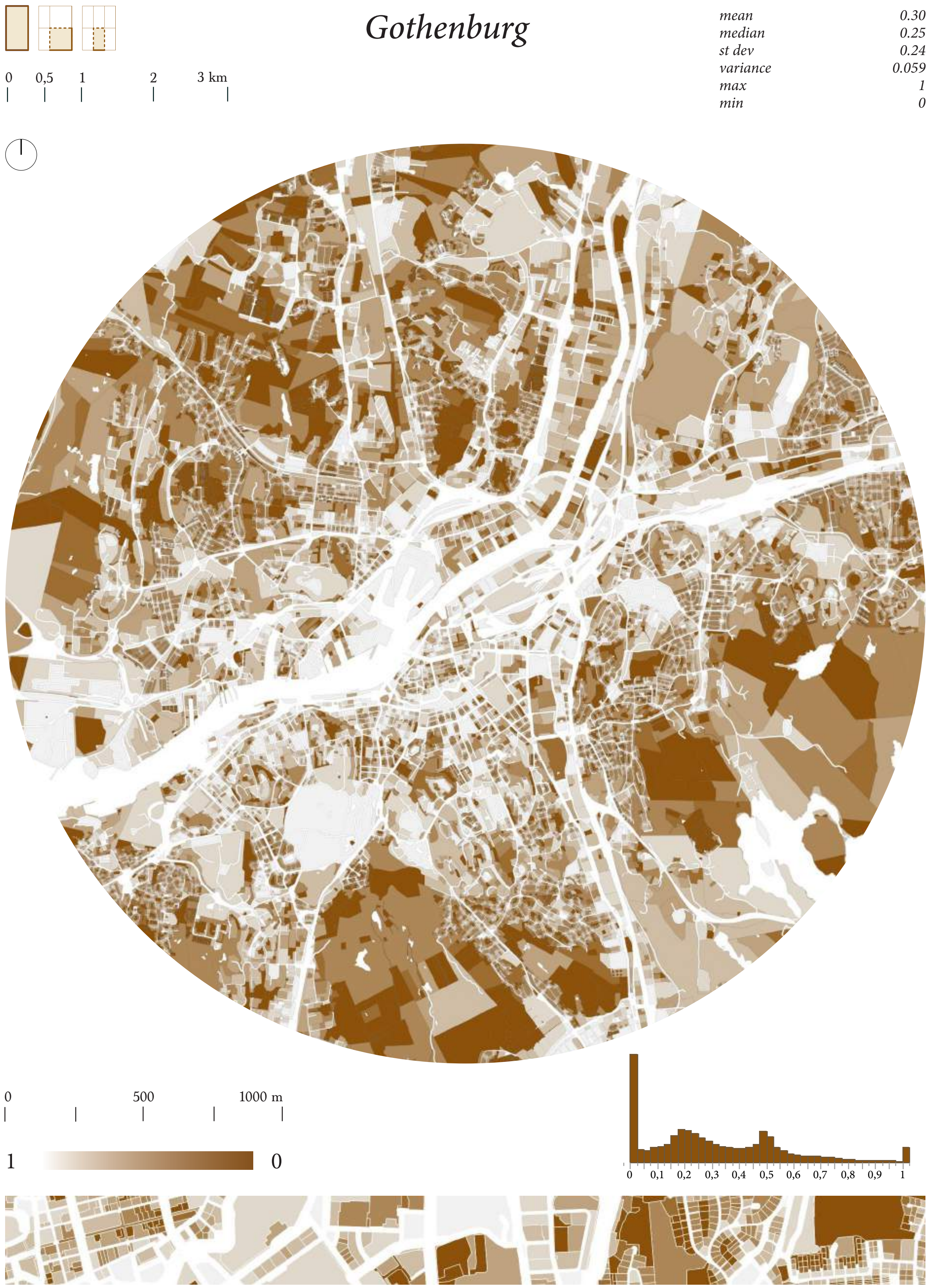
Stockholm

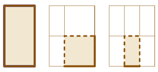
mean	*0.27*
median	*0.21*
st dev	*0.23*
variance	*0.051*
max	*1*
min	*0*








Gothenburg
mean 0.30
median 0.25
st dev 0.24
variance 0.059
max 1
min 0
0 0,5 1 2 3 km
0 500 1000 m
1 0
0 0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 1

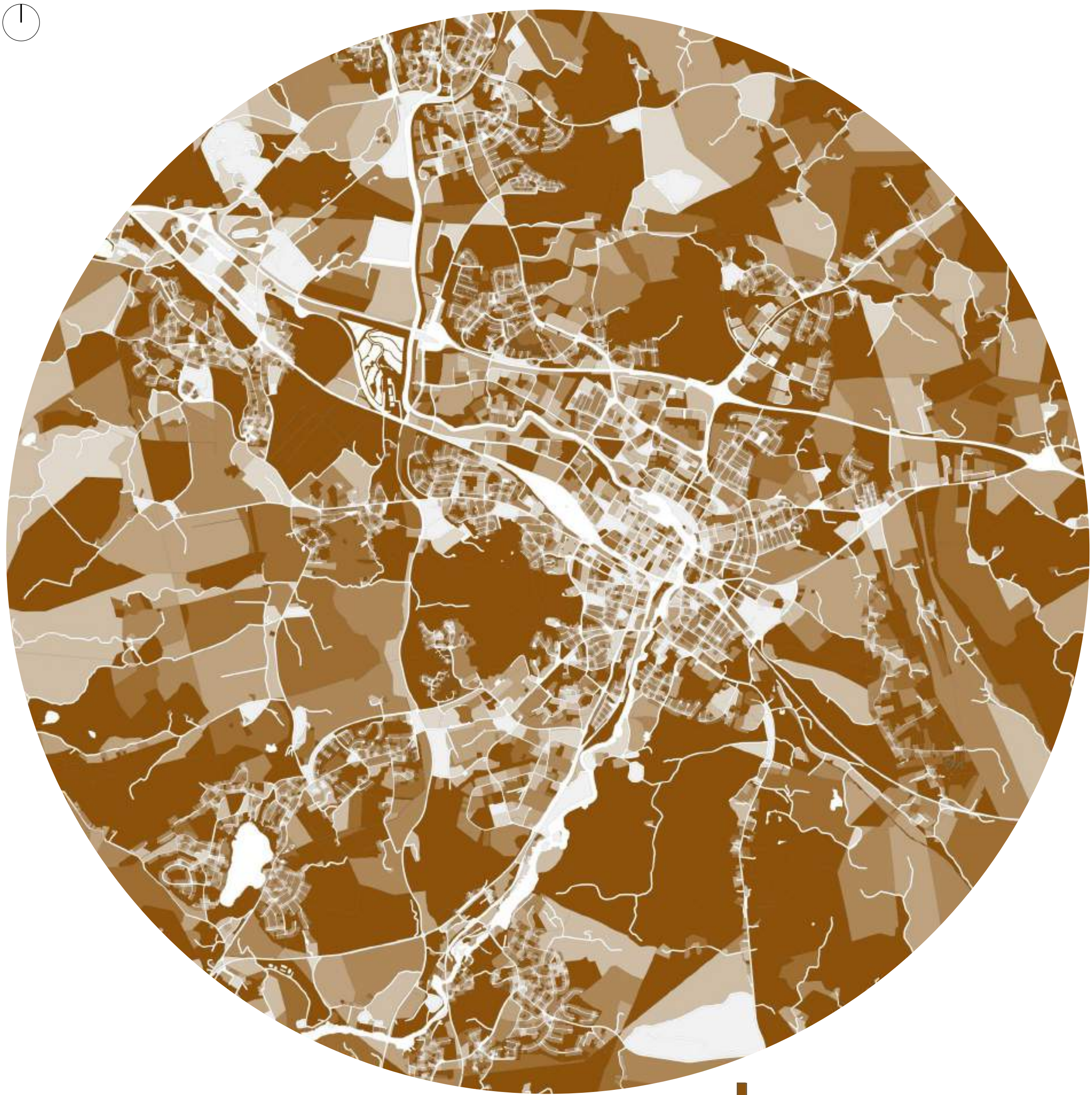


Frontage Index:

Eskilstuna

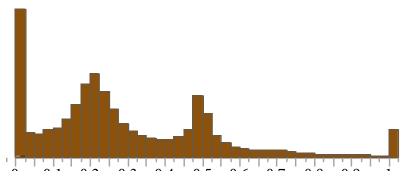
mean	*0.28*
median	*0.23*
st dev	*0.23*
variance	*0.053*
max	*1*
min	*0*

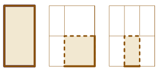
0 0,5 1 2 3 km



0 500 1000 m

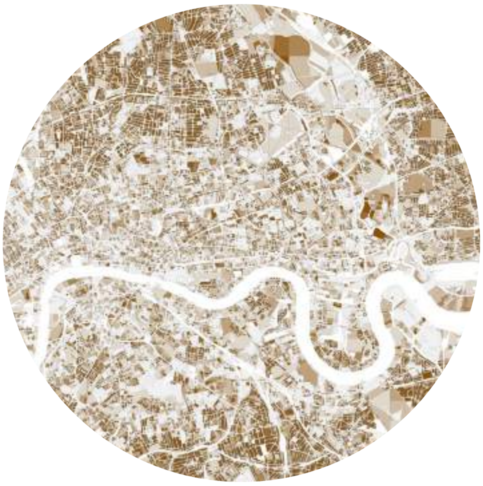
1 0





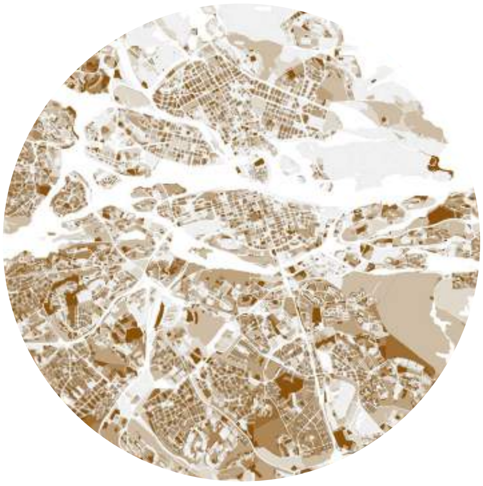
Five cities comparison

London

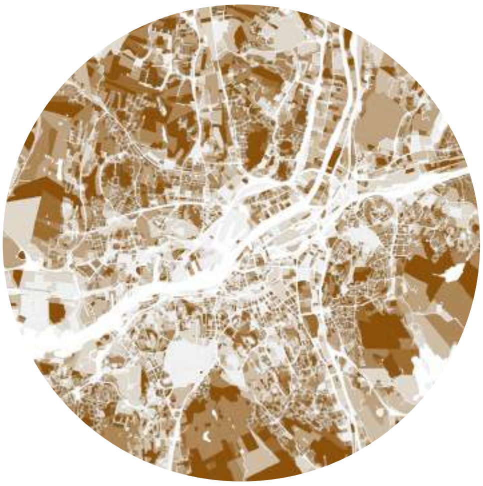


Amsterdam

Stockholm



Gothenburg

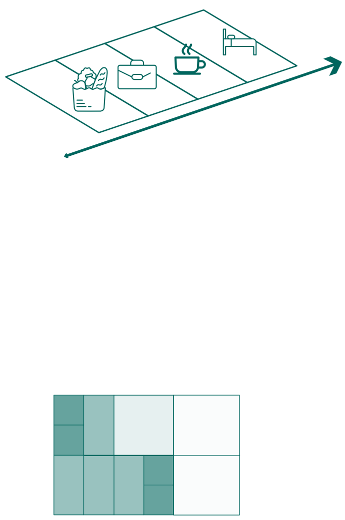


Eskilstuna

Frontage index in Amsterdam and London is much lower than in the three Swedish cities.

The distribution of plot frontage index is highly diverse, because plots with different frontage indices are often found next to each other. For example, regular urban block normally consists of corner plots with a higher frontage index than the row plots in between the corners.

Plots in space

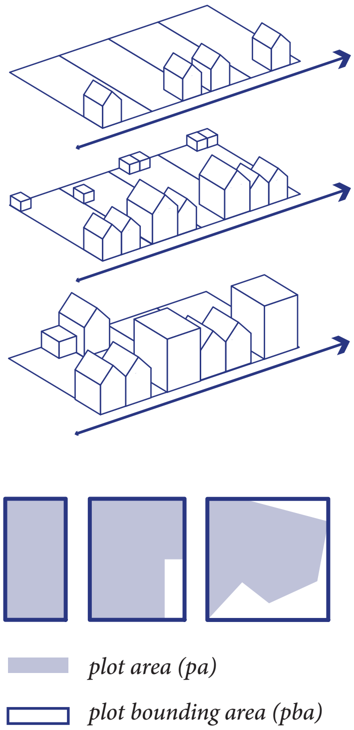


Accessible number of plots

AP (o;D) =AR (o;pc;D)*

pc = plot count

Plots in time

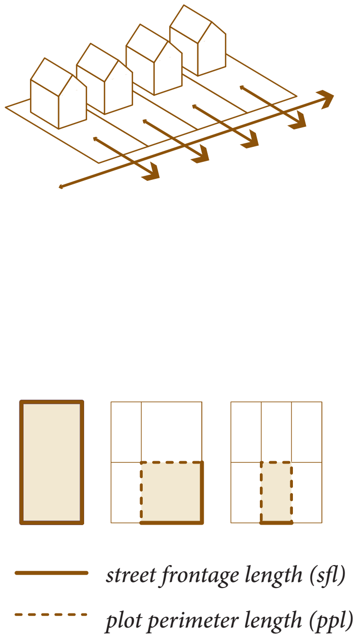


Accessible plot compactness index

APC (o;D) = AR (o;pa;D)/ AR (o;pba;D)*

pa = plot area
pba = plot bounding area

Plots as an interface



Accessible plot frontage index

APF (o;D) = AR (o;sfl;D)/ AR (o;ppl;D)*

sfl = street frontage length
ppl = plot perimeter length

*For all three measures:
AR = attraction reach
o = origin
D = 500m distance threshold

Accessibility measures of plots

Translating geometric to accessibility measures

Plot accessibility measures are calculated using a measure of accessibility and, more specifically, the cumulative-opportunities accessibility measure (Bhat et al., 2000) , with the distance threshold set at 500 m walking distance.

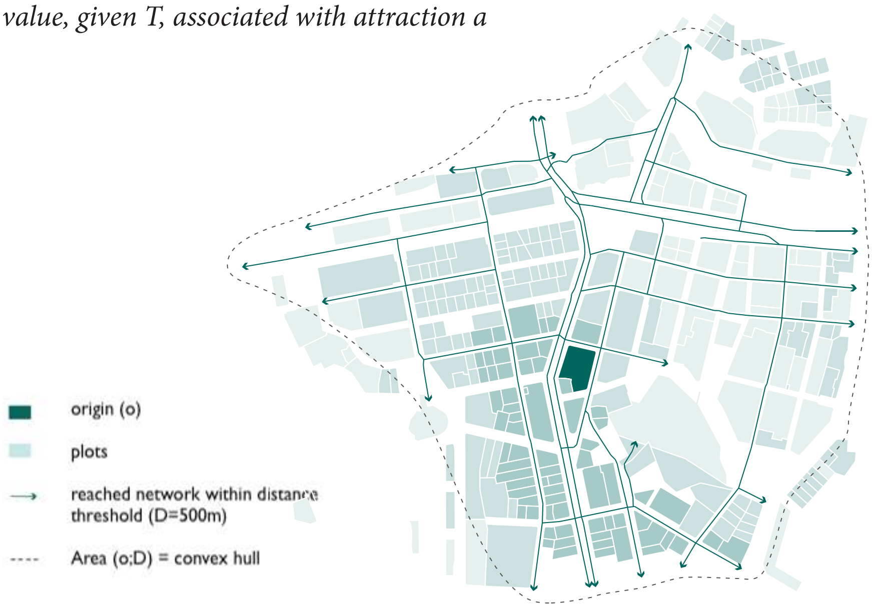
1. PST is plugin for QGIS. Software and documentation are available at https://www.smog.chalmers.se/pst.

For accessibility analysis PST [1](place syntax tool) is used. PST combines the space syntax description of the urban environment with conventional descriptions of attraction.

For all three accessibility measures, the general equation for attraction reach (AR) is used, as implemented in PST:

$$AR(o;T;D) = \sum_{a \in A(o;D)} f(a;T) \qquad (1)$$

where o = point of origin, a = an attraction (plot polygon), D = distance threshold (set to 500 m in this paper), A(o;D) = the set of reachable attractions, given o and D, T = type of measurement of interest (related to attraction); or 1, if no type of measurement is defined, f(a;T) = attraction value, given T, associated with attraction a



Descriptive statistics of accessibility measures

Descriptive statistics of accessibility measures

	LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA	TOTAL
area (sqkm)	3411	416,5	1084	733	72,5	
total N of observations	3069673	579405	381878	303835	94731	4429522
ACCESSIBLE NUMBER OF PLOTS						
mean (N)	462	426	97	65	62	390
median (N)	402	358	81	42	44	326
st dev	303	359.47	80.692	68.607	60.237	319.945
variance	92053.742	129218.613	6511.147	4706.985	3628.514	102364.573
max (N)	2574	2432	512	567	352	2574
min (N)	1	1	1	1	1	1
percentiles 25	244	166	29	14	10	143
50	402	358	81	42	44	326
75	621	577	145	96	99	556
ACCESSIBLE COMPACTNESS INDEX						
mean	0.74	0.67	0.65	0.63	0.65	0.72
median	0.76	0.68	0.67	0.64	0.66	0.74
st dev	0.11	0.14	0.15	0.13	0.15	0.13
variance	.012	0.020	0.022	0.017	0.022	0.016
max	1	1	1	0.99	1	1
min	0.007	0.008	0	0.01	0.006	0
percentiles 25	0.68	0.58	0.55	0.56	0.57	0.65
50	0.76	0.68	0.67	0.64	0.66	0.74
75	0.82	0.78	0.76	0.72	0.76	0.81
ACCESSIBLE FRONTAGE INDEX						
mean	0.22	0.27	0.31	0.31	0.27	0.25
median	0.20	0.25	0.29	0.30	0.27	0.22
st dev	0.09	0.10	0.13	0.15	0.14	0.11
variance	.009	0.010	0.018	0.023	0.020	0.012
max	1	1	1	1	1	1
min	0	0	0	0	0	0
percentiles 25	0.17	0.21	0.24	0.24	0.20	0.18
50	0.20	0.25	0.29	0.30	0.27	0.22
75	0.25	0.31	0.35	0.37	0.32	0.28

- *When both maximum and average values are compared, London and Amsterdam have approx **5-6 times** more plots reachable within 500m walking distance than Swedish cities.*

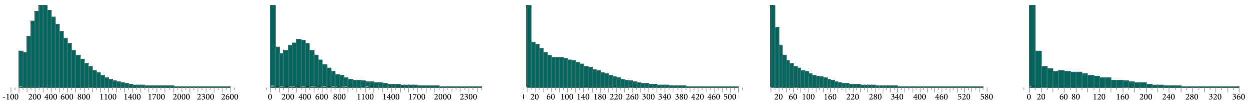
- *London has on average the most compact plots as perceived within 500m walking distance, compared to Amsterdam and Swedish cities, where these values are relatively similar.*

- *Accessible plot frontage index is on average the smallest in London, followed by Amsterdam and Eskilstuna, and the largest in Stockholm and Gothenburg*

Distributions

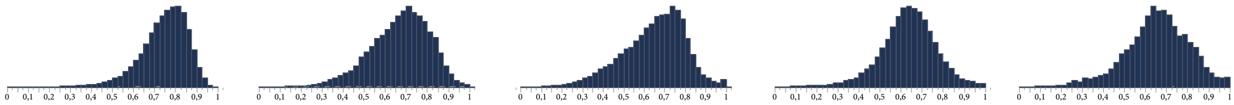
LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA
3411	*416,5*	*1084*	*733*	*72,5*
3069673	*579405*	*381878*	*303835*	*94731*

ACCESSIBLE NUMBER OF PLOTS*

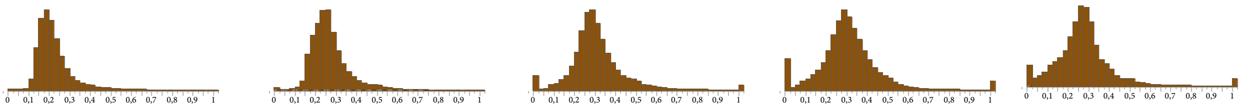


**Distributions for accessible number of plots are shown relative for each city. For accessible number of plots measured in the same scale see comparative maps.*

ACCESSIBLE COMPACTNESS INDEX



ACCESSIBLE FRONTAGE INDEX



- *When distributions of accessible number of plots are accessed, London demonstrates the most number of plots that are also surrounded by many other plots within 500m walking distance.*

- *Distributions of accessible compactness index values are relatively the same between cities, though London and Amsterdam are characterised by the presence of more compact plots*

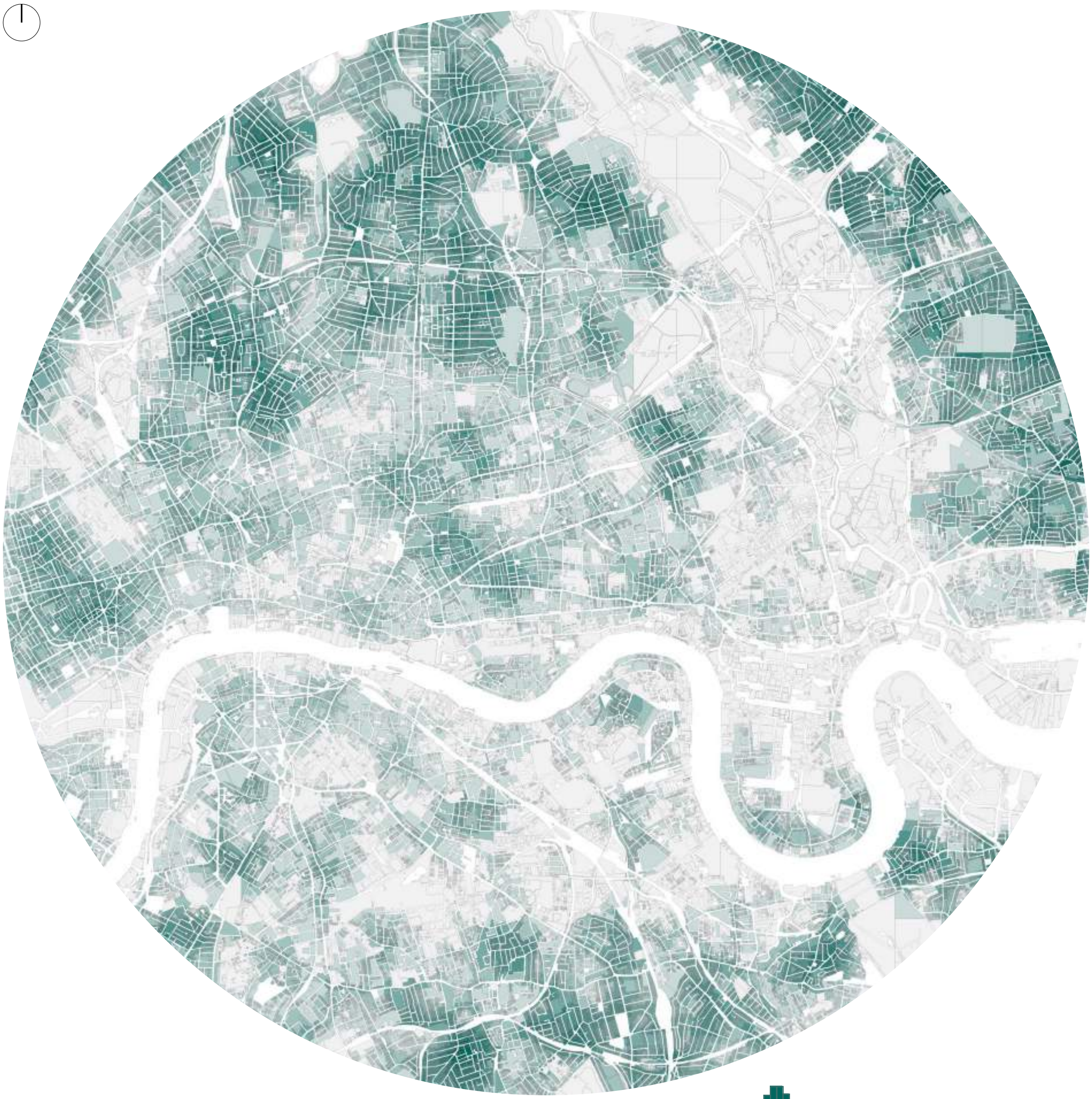
- *Distributions of accessible frontage index values shows that London has the most narrow plots in general and least number of plots that do not have any access to any street interface* ***(zero values)****.*

Accessible number of plots:

London

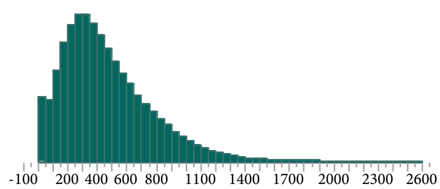
mean (N)	*462*
median (N)	*402*
st dev	*303*
variance	*92053.742*
max (N)	*2574*
min (N)	*1*

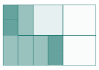
0 0,5 1 2 3 km



0 500 1000 m

1 2574





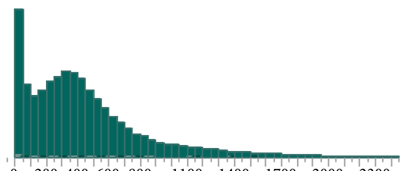
Amsterdam

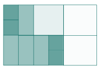
mean (N)	*426*
median (N)	*358*
st dev	*359.47*
variance	*129218.613*
max (N)	*2432*
min (N)	*1*

0 0,5 1 2 3 km

0 500 1000 m

1 2432

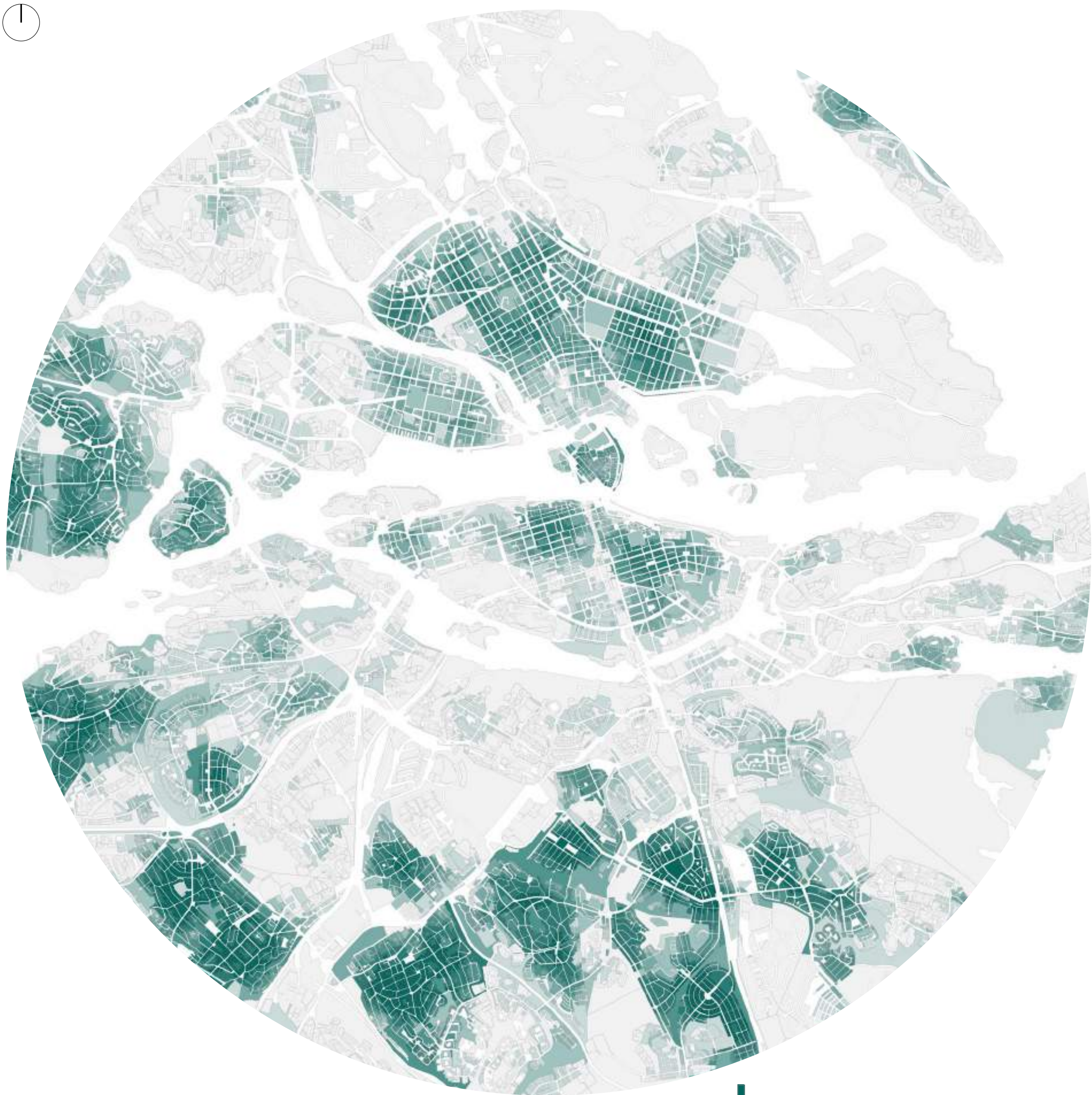




0 0,5 1 2 3 km

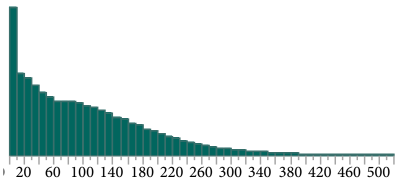
Accessible number of plots:
Stockholm

mean (N)	*97*
median (N)	*81*
st dev	*80.692*
variance	*6511.147*
max (N)	*512*
min (N)	*1*



0 500 1000 m

1 512



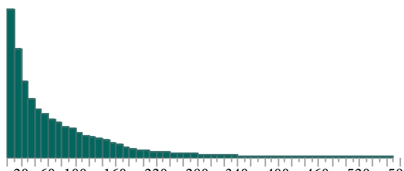
Gothenburg

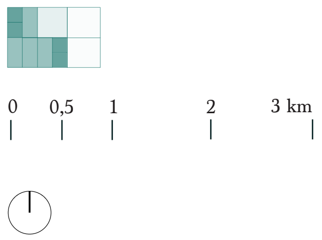
mean (N)	*65*
median (N)	*42*
st dev	*68.607*
variance	*4706.985*
max (N)	*567*
min (N)	*1*

0 0,5 1 2 3 km

0 500 1000 m

1 567

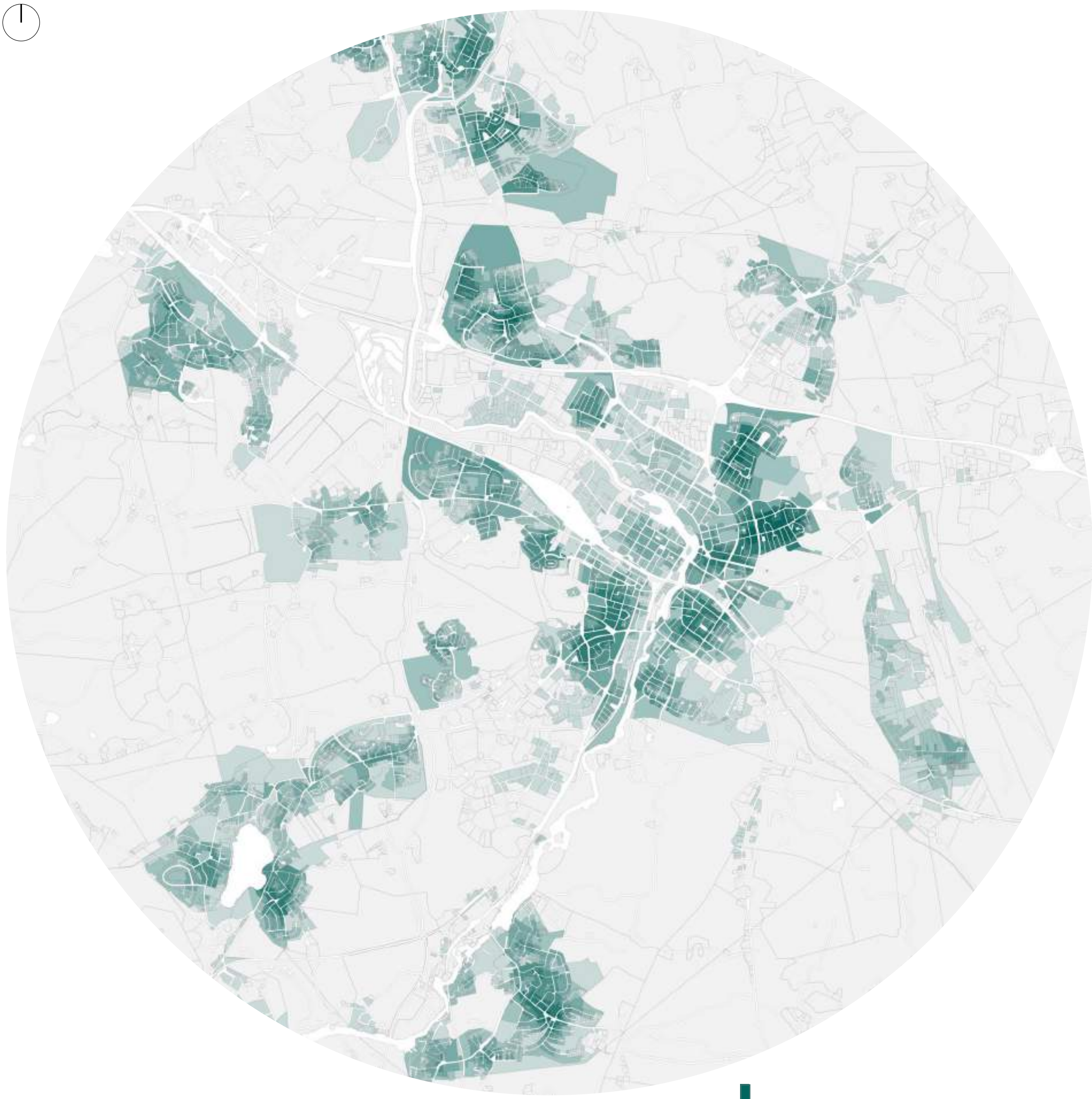


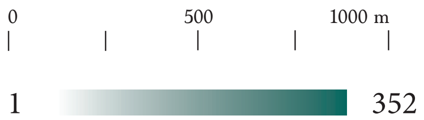


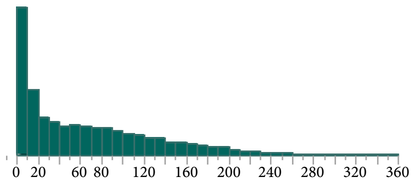
Accessible number of plots:

Eskilstuna

mean (N)	*62*
median (N)	*44*
st dev	*60.237*
variance	*3628.514*
max (N)	*352*
min (N)	*1*



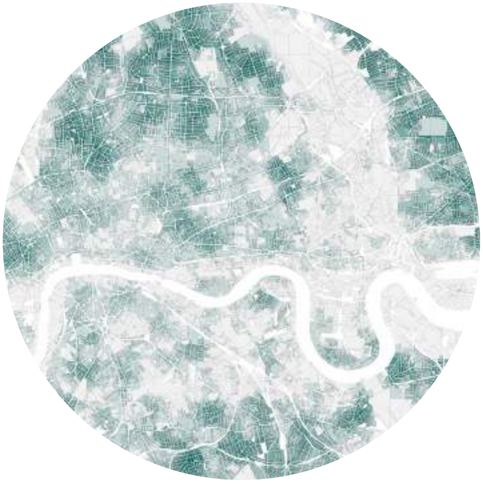




Five cities comparison

0 1 5km

London



Amsterdam

Stockholm

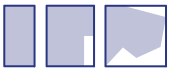
Gothenburg

Eskilstuna

In line with the smaller size of plots in Amsterdam and London in comparison to the Swedish cities, London and Amsterdam have approximately five to six times more accessible plots than the Swedish cities. Amsterdam has the highest values in the city centre, while in the other cities, and most prominent in London, the highest values of accessible number of plots are found outside the city core.

**For the comparison between cities, similar ranges are used in each city, where maximum value of accessible number of plots is set to 2574: maximum value found in London*

1 2574



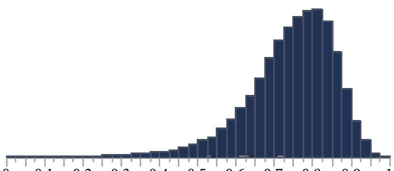
0 0,5 1 2 3 km

Accessible compactness index: London

mean	*0.74*
median	*0.76*
st dev	*0.11*
variance	*.012*
max	*1*
min	*0.007*

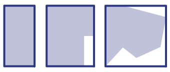
0 500 1000 m

0 1



Amsterdam

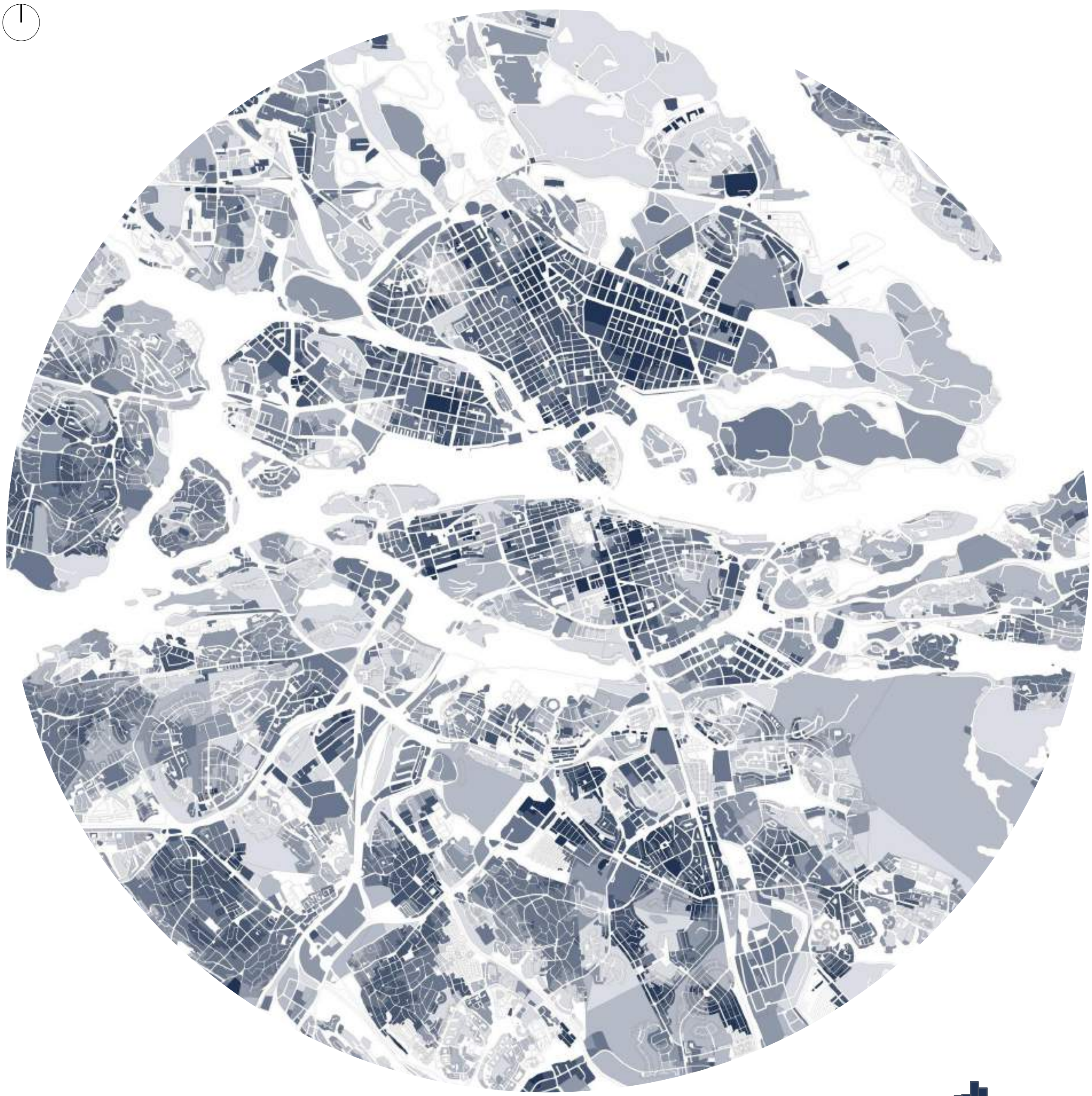
mean	*0.67*
median	*0.68*
st dev	*0.14*
variance	*0.020*
max	*1*
min	*0.008*



0 0,5 1 2 3 km

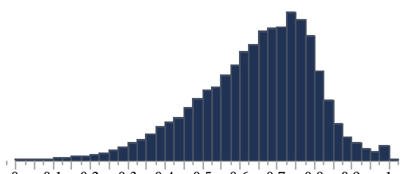
Accessible compactness index: Stockholm

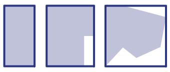
mean	*0.65*
median	*0.67*
st dev	*0.15*
variance	*0.022*
max	*1*
min	*0*



0 500 1000 m

0 1

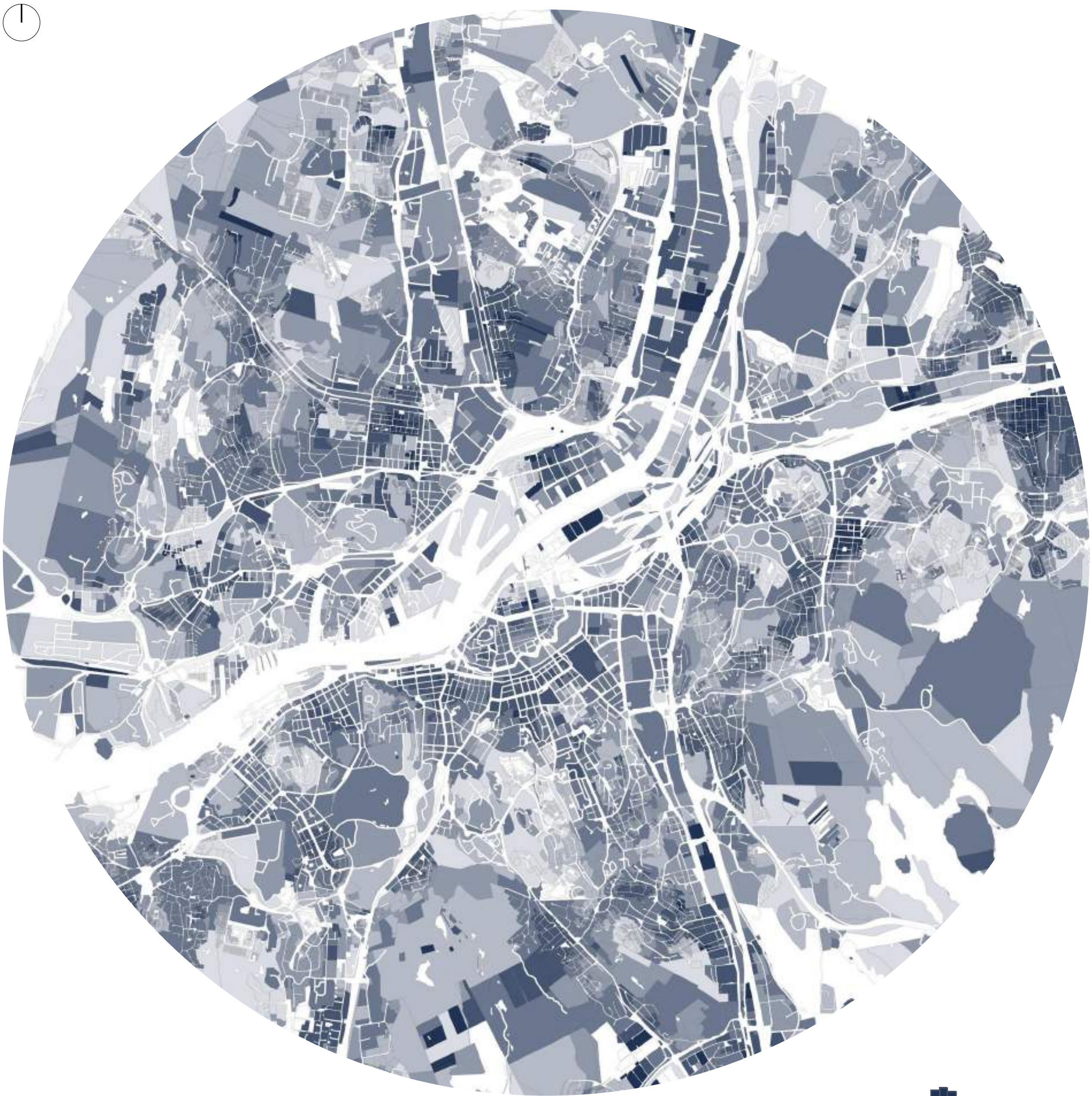




0 0,5 1 2 3 km

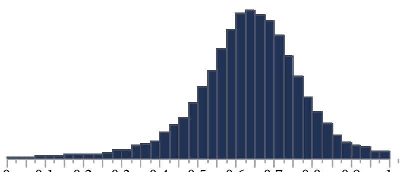
Gothenburg

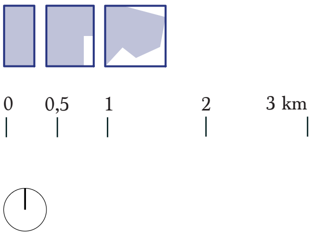
mean	*0.63*
median	*0.64*
st dev	*0.13*
variance	*0.017*
max	*0.99*
min	*0.01*



0 500 1000 m

0 1

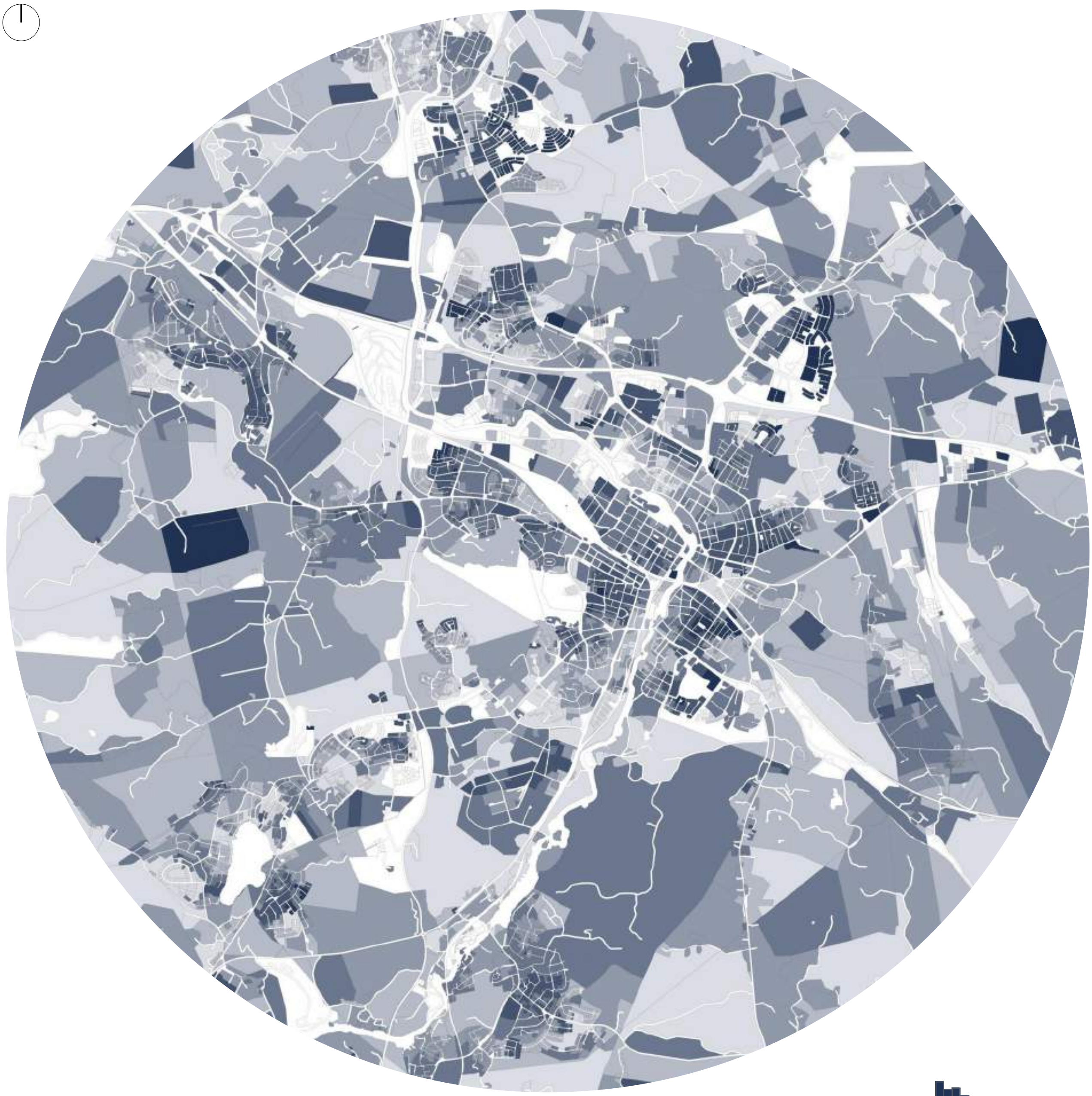


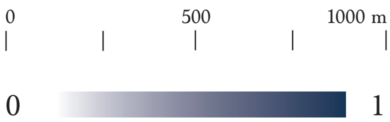


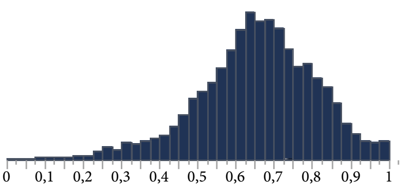
Accessible compactness index:

Eskilstuna

mean	*0.65*
median	*0.66*
st dev	*0.15*
variance	*0.022*
max	*1*
min	*0.006*







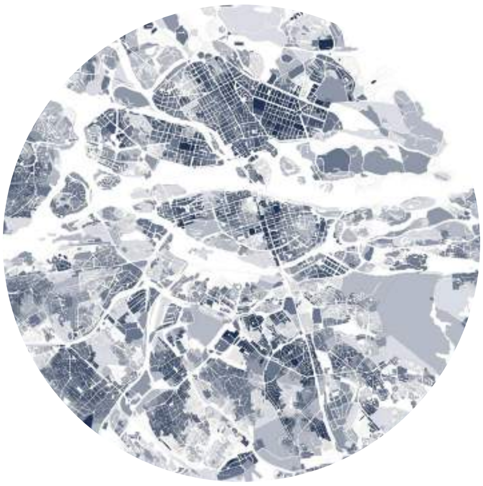
Five cities comparison

0 1 5km

London

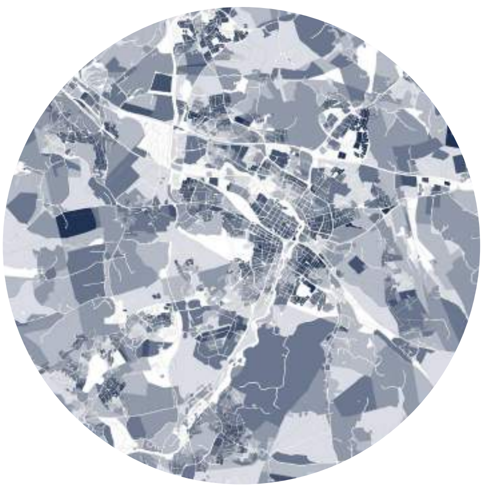
Amsterdam

Stockholm



Gothenburg

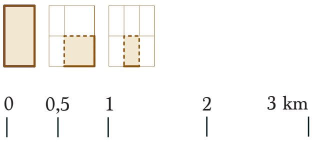
Eskilstuna



London has the highest accessible plot compactness index in general, while the other four cities have comparable mean values.

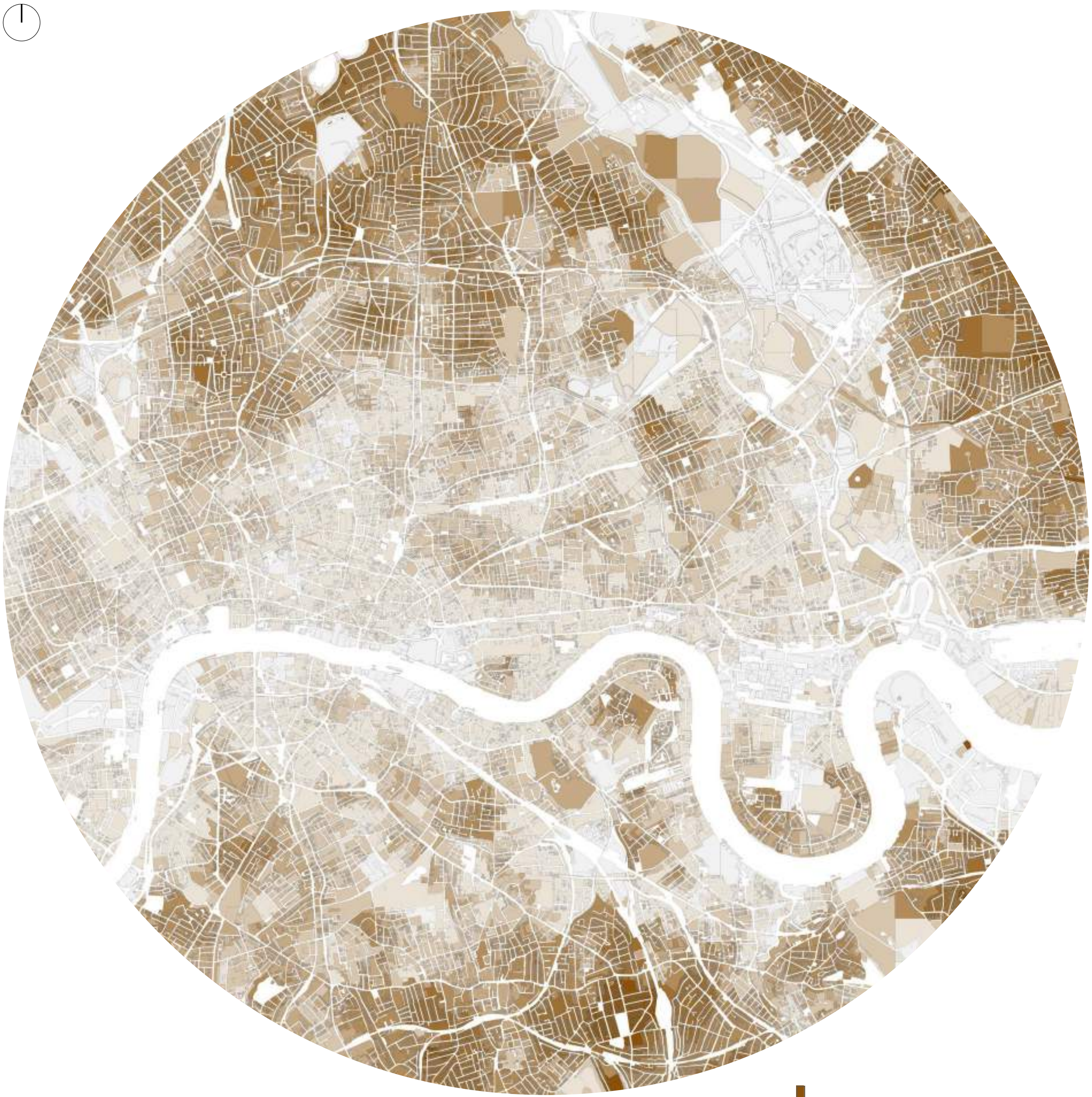
Most compact plot patterns are found in urbanised urban city centres, but high accessible compactness can also be found in other areas, most prominent in industrial areas. (urban fringes are exceptions, but they are well seen due to large size)

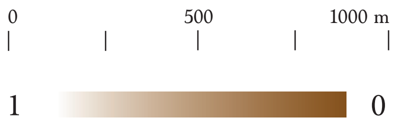
0 1

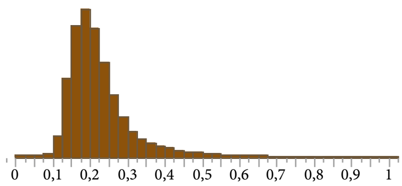


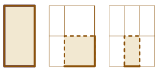
Accessible frontage index: London

mean	*0.22*
median	*0.20*
st dev	*0.09*
variance	*.009*
max	*1*
min	*0*









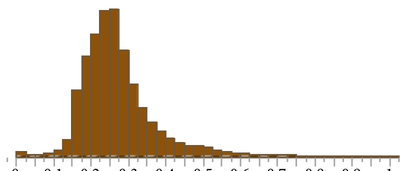
0 0,5 1 2 3 km

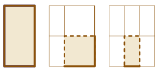
Amsterdam

mean	*0.27*
median	*0.25*
st dev	*0.10*
variance	*0.010*
max	*1*
min	*0*

0 500 1000 m

1 0

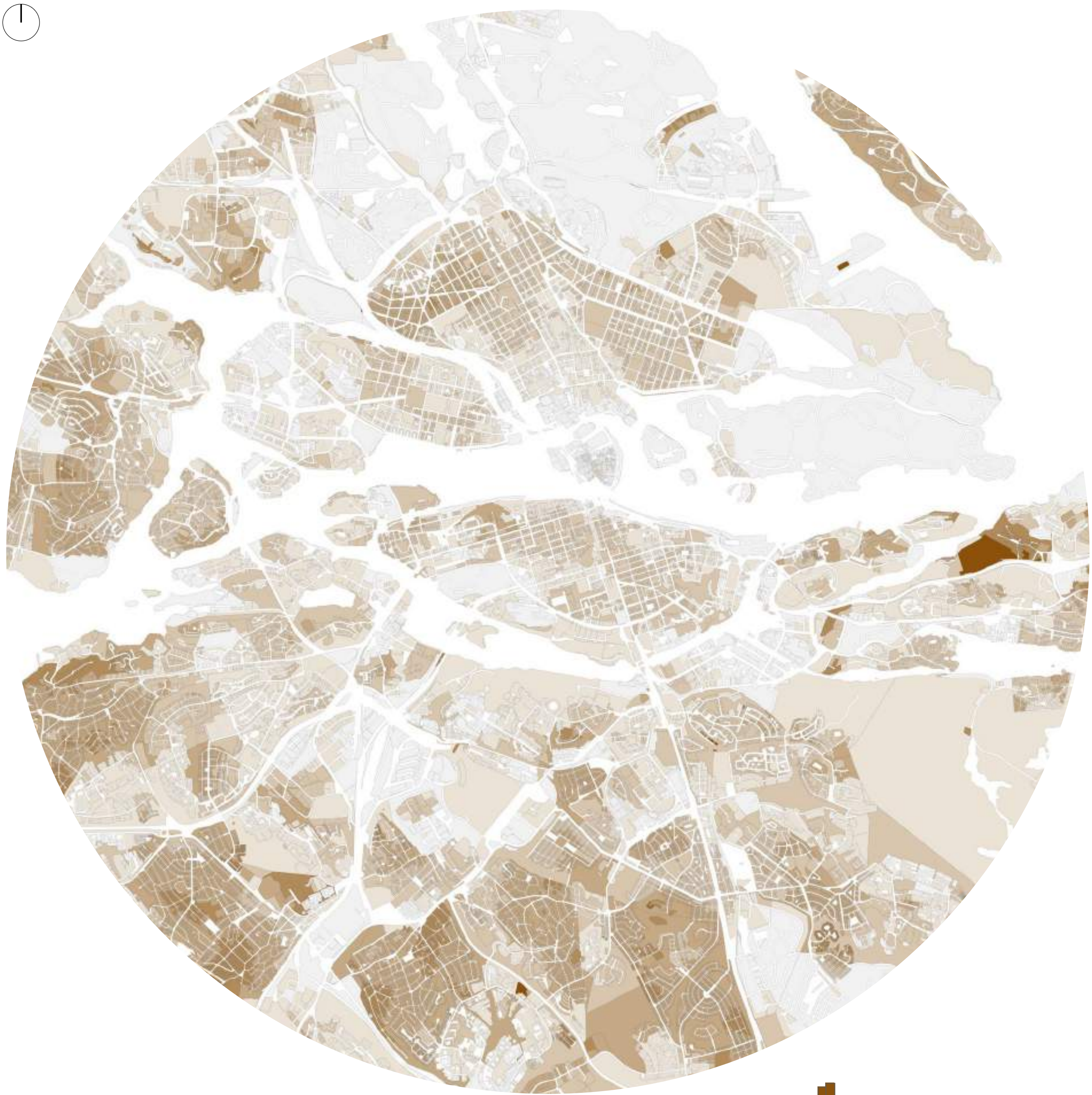




Accessible frontage index:
Stockholm

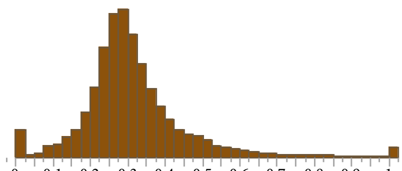
mean	0.31
median	0.29
st dev	0.13
variance	0.018
max	1
min	0

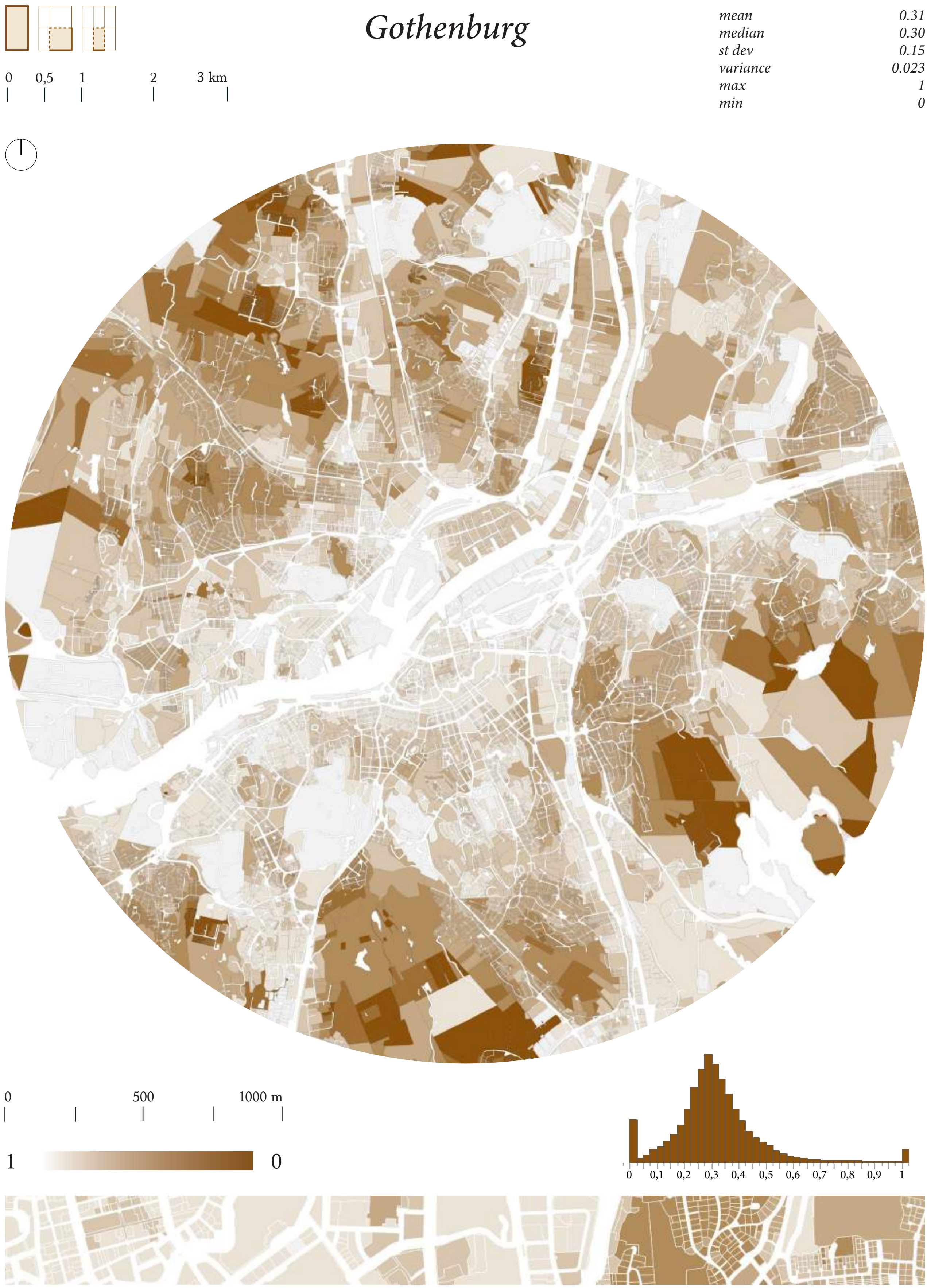
0 0,5 1 2 3 km

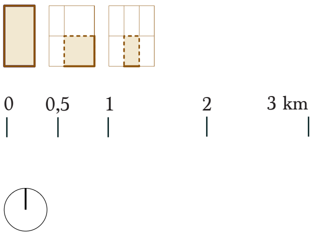


0 500 1000 m

1  0



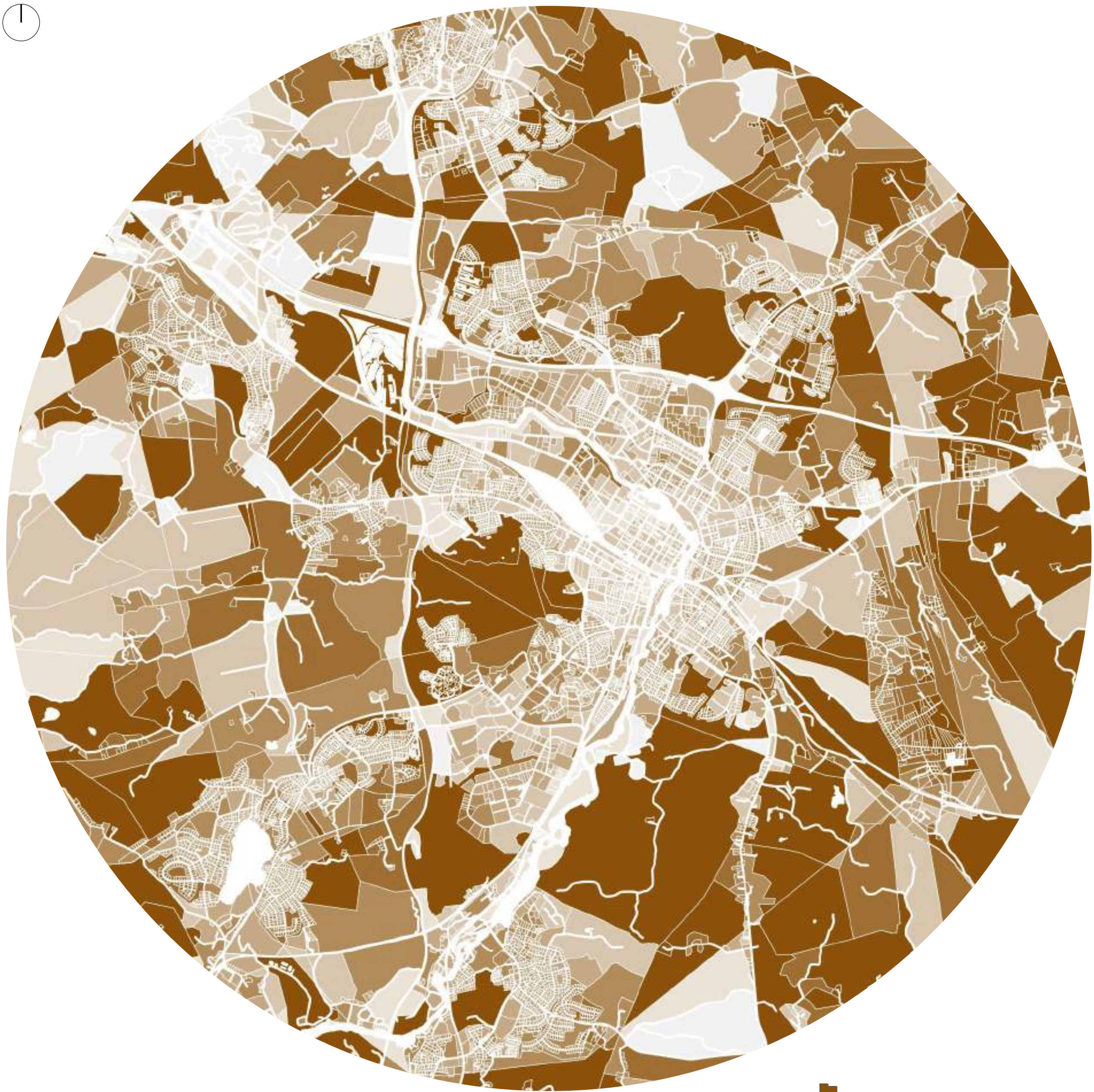

Gothenburg
mean 0.31
median 0.30
st dev 0.15
variance 0.023
max 1
min 0
0 0,5 1 2 3 km
0 500 1000 m
1 0
0 0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 1

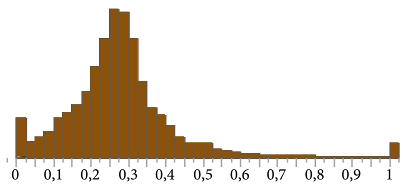


Accessible frontage index:

Eskilstuna

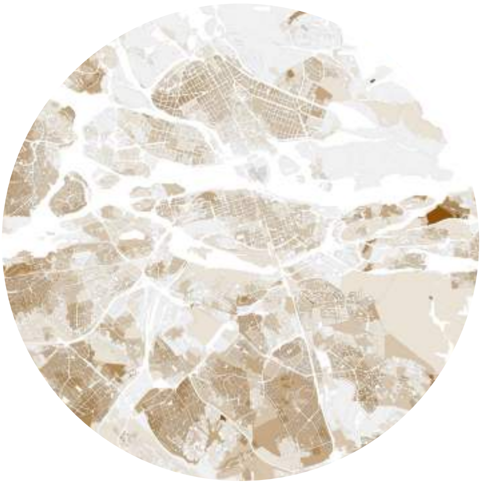
mean	*0.27*
median	*0.27*
st dev	*0.14*
variance	*0.020*
max	*1*
min	*0*





Five cities comparison

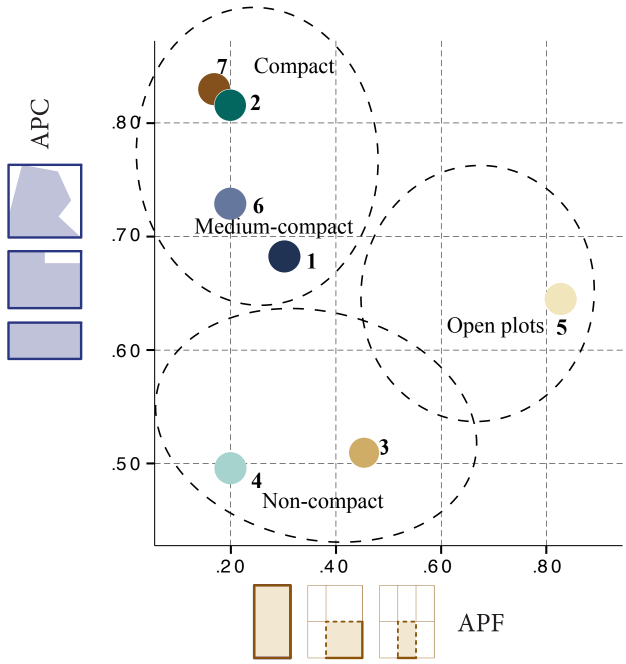
0 1 5km



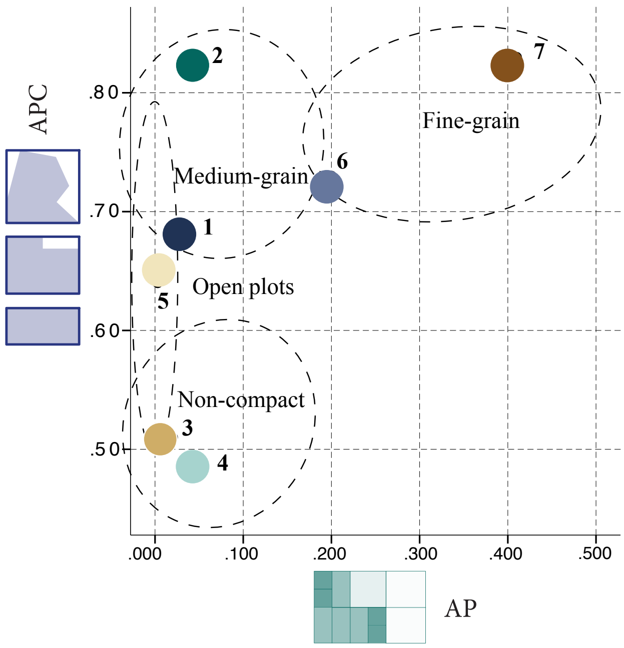
London has the lowest frontage index in comparison to the other cities.

In Amsterdam, low values are concentrated in the city centre, while in the other cities, plot patterns with high frontage indices dominate the central areas.

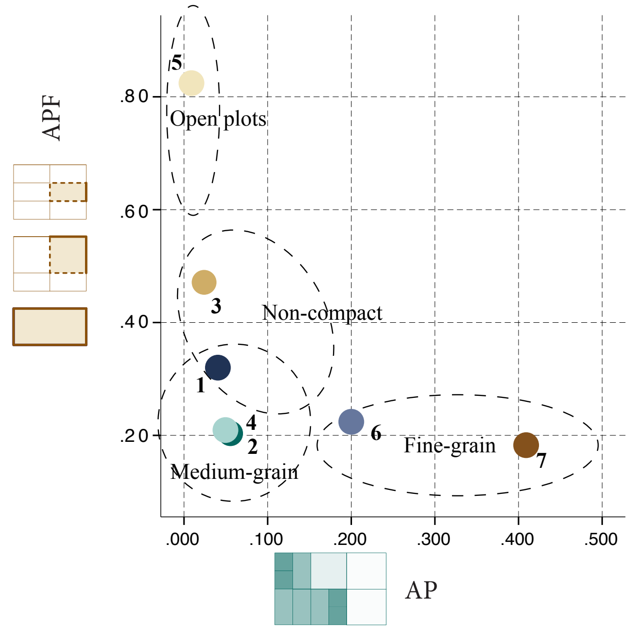
1 0



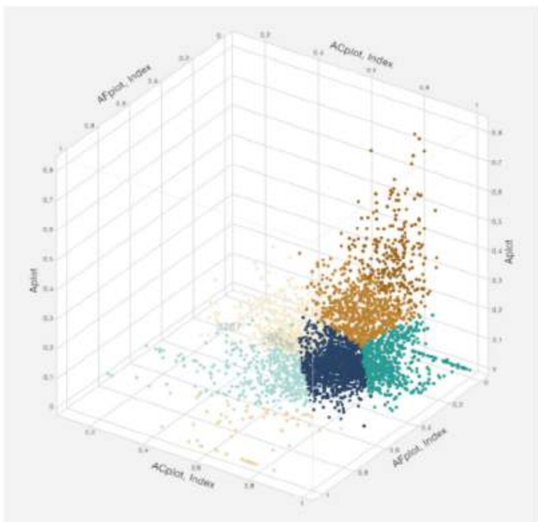
A. APC (accessible compactness index)
+ APF (accessible frontage index)



B. APC (accessible compactness index)
+ AP (accessible number of plots)



C. APF (accessible frontage index)
+ AP (accessible number of plots)



PT7 Fine-grain compact
PT6 Fine-grain medium-compact
PT1 Medium-grain medium-compact
PT2 Medium-grain compact
PT4 Medium-grain non-compact
PT3 Large-grain non-compact
PT5 Open plots

Plot types

From measures to types

Types are a powerful way to describe complex patterns.

To develop plot type unsupervised statistical clustering analysis is used. The input variables for classification are the three accessibility measures of plots developed deductively based on urban morphological theories.

To perform the classification, k-means cluster analysis is used, that is a common technique for statistical data analysis, which groups observations in groups in such a way, that observations in one group are more similar to each other, than to observations in other groups.

The classification of plots resulted in the seven plot types. The scatterplots demonstrate that the variables taken separately cannot capture the differences between types, but together contribute to their formation.

Types overview:

cluster centroids and distributions across cities

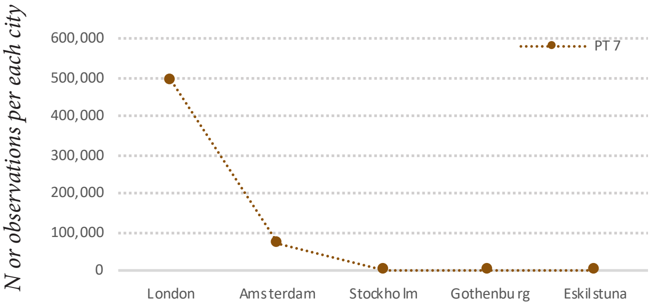
FINE-GRAIN

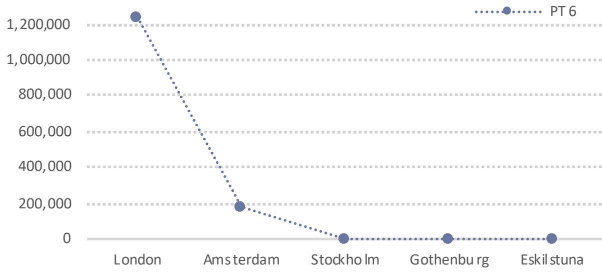
PT 7
FINE-GRAIN
COMPACT

AP	*0,41(1055)**
APC	*0,83*
APF	*0,18*

PT 6
FINE-GRAIN
MEDIUM-COMPACT

AP	*0,20(515)**
APC	*0,73*
APF	*0,22*

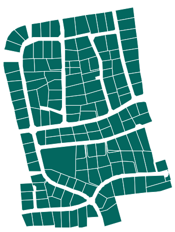




MEDIUM-GRAIN

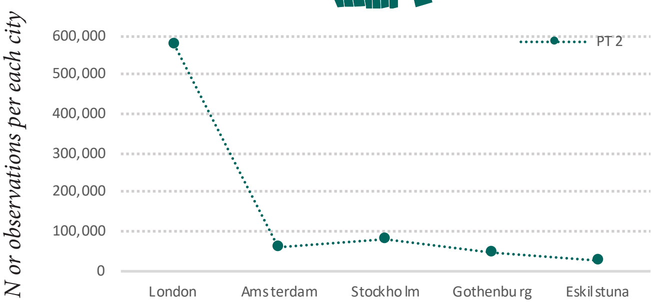
PT 2
MEDIUM-GRAIN
COMPACT

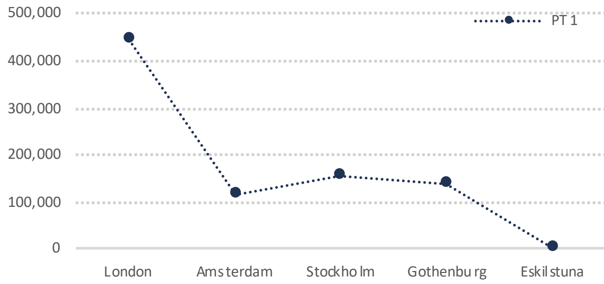
AP	*0,05 (129)**
APC	*0,82*
APF	*0,21*



PT 1
MEDIUM-GRAIN
MEDIUM-COMPACT

AP	*0,04 (103)**
APC	*0,68*
APF	*0,32*





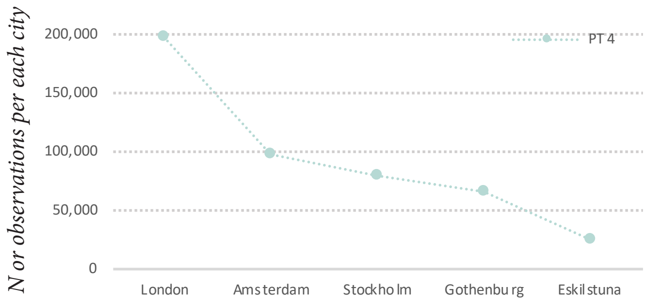
NON-COMPACT

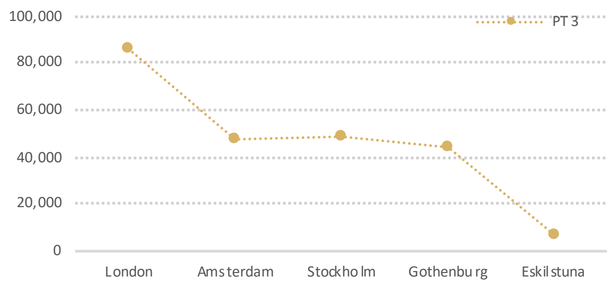
PT 4
MEDIUM-GRAIN
NON-COMPACT

AP	*0,05 (129)**
APC	*0,49*
APF	*0,21*

PT 3
LARGE-GRAIN
NON-COMPACT

AP	*0,02 (52)**
APC	*0,51*
APF	*0,46*



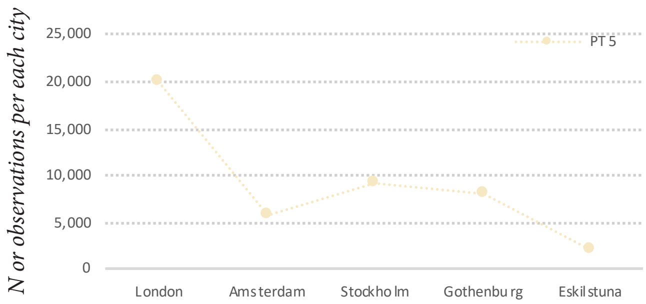


OPEN PLOTS

PT 5
OPEN PLOTS

AP	*0,003 (8)**
APC	*0,63*
APF	*0,83*

AP	*Accessible number of plots*
APC	*Accessible plot compactness index*
APF	*Accessible plot frintage index*



**While the values for the APF and APC range from 0 to 1, the AP is measured in absolute values (shown in brackets). In order to perform cluster analysis the AP also had to be scaled to a range from 0 to 1, where 1 equals the maximum possible accessible numbers of plots which equals 2574 plots in London). The rescaled number is shown next to the one in brackets*

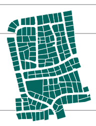
Types overview: descriptive statistics of plot types

Descriptive statistics of plot types

	LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA
PT 7 Fine-grain compact					
N	495665	73383	0	0	0
AP*					**Accessible number of plots**
mean	0,38 (979)	0,45 (1150)	–	–	–
median	0,36 (921)	0,42 (1083)			
variance	0,009	0,01			
APC					**Accessible plot compactness index**
mean	0,84	0,81	–	–	–
median	0,84	0,82			
variance	0,003	0,004			
APF					**Accessible plot frontage index**
mean	0,17	0,19	–	–	–
median	0,17	0,18			
variance	0,001	0,001			

	LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA
PT 6 Fine-grain medium-compact					
N	1245906	184507	5946	2223	89
AP*					**Accessible number of plots**
mean	0,20 (506)	0,2 (532)	0,12 (317)	0,13 (330)	0,09 (233)
median	0,19 (499)	0,2 (519)	0,12 (313)	0,13 (327)	0,09 (233)
variance	0,003	0,003	0,0004	0,0008	0,0001
APC					**Accessible plot compactness index**
mean	0,75	0,7	0,72	0,72	0,67
median	0,75	0,7	0,73	0,73	0,66
variance	0,005	0,005	0,002	0,002	0,001
APF					**Accessible plot frontage index**
mean (m^2)	0,20	0,24	0,24	0,25	0,12
median (m^2)	0,20	0,24	0,24	0,26	0,10
variance	0,002	0,002	0,002	0,002	0,005

	LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA
PT 1 Medium-grain medium-compact					
N	442999	113659	156375	139771	36665
AP*					**Accessible number of plots**
mean	(0,07)191	0,07 (192)	0,04 (96)	0,03 (70)	0,02 (62)
median	(0,07)188	0,08 (194)	0,03 (84)	0,02 (53)	0,02 (48)
variance	0,002	0,002	0,0007	0,0005	0,0004
APC					**Accessible plot compactness index**
mean	0,68	0,67	0,69	0,68	0,68
median	0,68	0,67	0,69	0,67	0,68
variance	0,003	0,004	0,004	0,003	0,003
APF					**Accessible plot frontage index**
mean	0,31	0,32	0,32	0,32	0,30
median	0,30	0,32	0,31	0,32	0,30
variance	0,005	0,005	0,004	0,004	0,004



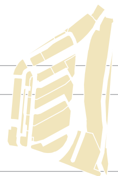
	LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA
PT 2 Medium-grain compact					
N	581081	56983	82569	43615	24010
AP*					**Accessible number of plots**
mean	0,1 (259)	0,05(144)	0,05 (117)	0,03(68)	0,03 (83)
median	0,1 (256)	0,04 (115)	0,04 (109)	0,01 (29)	0,03 (75)
variance	0,002	0,002	0,001	0,001	0,0006
APC					**Accessible plot compactness index**
mean	0,82	0,82	0,81	0,81	0,82
median	0,82	0,83	0,80	0,80	0,82
variance	0,003	0,005	0,004	0,006	0,006
APF					**Accessible plot frontage index**
mean	0,19	0,21	0,23	0,18	0,23
median	0,19	0,22	0,25	0,21	0,25
variance	0,002	0,006	0,008	0,014	0,009
	LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA

Descriptive statistics of plot types

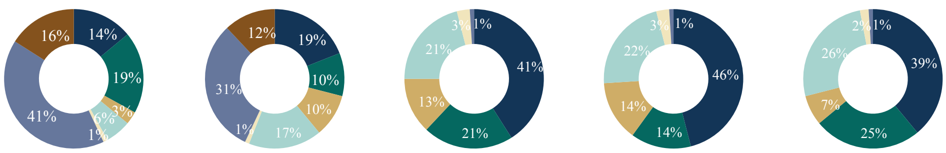
	LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA
PT 4 Medium-grain non-compact					
N	198146	98062	79274	66018	25327
AP*					**Accessible number of plots**
mean	0,11 (285)	0,12 (296)	0,04 (106)	0,03 (74)	0,02 (58)
median	0,10 (268)	0,12 (297)	0,04 (96)	0,02 (55)	0,01 (38)
variance	0,003	0,004	0,0007	0,0006	0,0005
APC					**Accessible plot compactness index**
mean	0,51	0,49	0,47	0,50	0,50
median	0,53	0,5	0,49	0,52	0,52
variance	0,006	0,007	0,009	0,008	0,010
APF					**Accessible plot frontage index**
mean	0,21	0,25	0,22	0,21	0,17
median	0,22	0,26	0,23	0,22	0,18
variance	0,005	0,003	0,005	0,006	0,006

	LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA
PT 3 Large-grain non-compact					
N	85787	47149	48545	44305	6591
AP*					**Accessible number of plots**
mean	0,04 (98)	0,04 (112)	0,01 (34)	0,01 (31)	0,004 (12)
median	0,03 (67)	0,03 (67)	0,01(19)	0,01 (18)	0,002 (6)
variance	0,001	0,002	0,0002	0,0002	0,00004
APC					**Accessible plot compactness index**
mean	0,54	0,49	0,50	0,51	0,51
median	0,55	0,51	0,52	0,54	0,54
variance	0,01	0,01	0,01	0,01	0,02
APF					**Accessible plot frontage index**
mean	0,47	0,45	0,46	0,46	0,47
median	0,46	0,44	0,45	0,45	0,47
variance	0,007	0,006	0,006	0,006	0,006

	LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA
PT 5 Open plots					
N	20089	5662	9169	7903	2049
AP*					**Accessible number of plots**
mean	0,009 (23)	0,006 (17)	0,004 (10)	0,002 (5)	0,001 (4)
median	0,004 (10)	0,003 (8)	0,001 (3)	0,0003 (1)	0,0003 (1)
variance	0,0002	0,00008	0,00008	0,00001	0
APC					**Accessible plot compactness index**
mean	0,62	0,67	0,65	0,64	0,65
median	0,63	0,68	0,66	0,65	0,66
variance	0,019	0,029	0,015	0,014	0,014
APF					**Accessible plot frontage index**
mean	0,76	0,75	0,82	0,86	0,87
median	0,73	0,72	0,79	0,90	0,95
variance	0,015	0,01	0,021	0,021	0,02



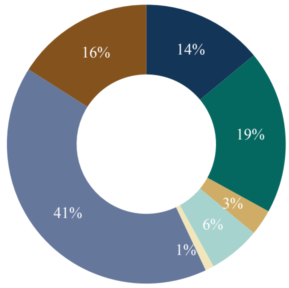
SUMMARY PLOT TYPES DISTRIBUTIONS WITHIN EACH CITY



LONDON AMSTERDAM STOCKHOLM GOTHENBURG ESKILSTUNA

**While the values for the APF and APC range from 0 to 1, the AP is measured in absolute values (shown in brackets). In order to perform cluster analysis the AP also had to be scaled to a range from 0 to 1, where 1 equals the maximum possible accessible numbers of plots which equals 2574 plots in London). The rescaled number is shown next to the one in brackets. Variance is also shown for rescaled number*

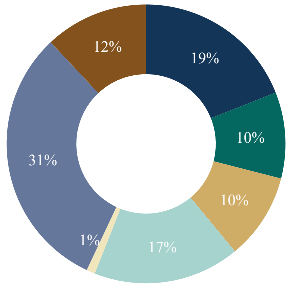
London

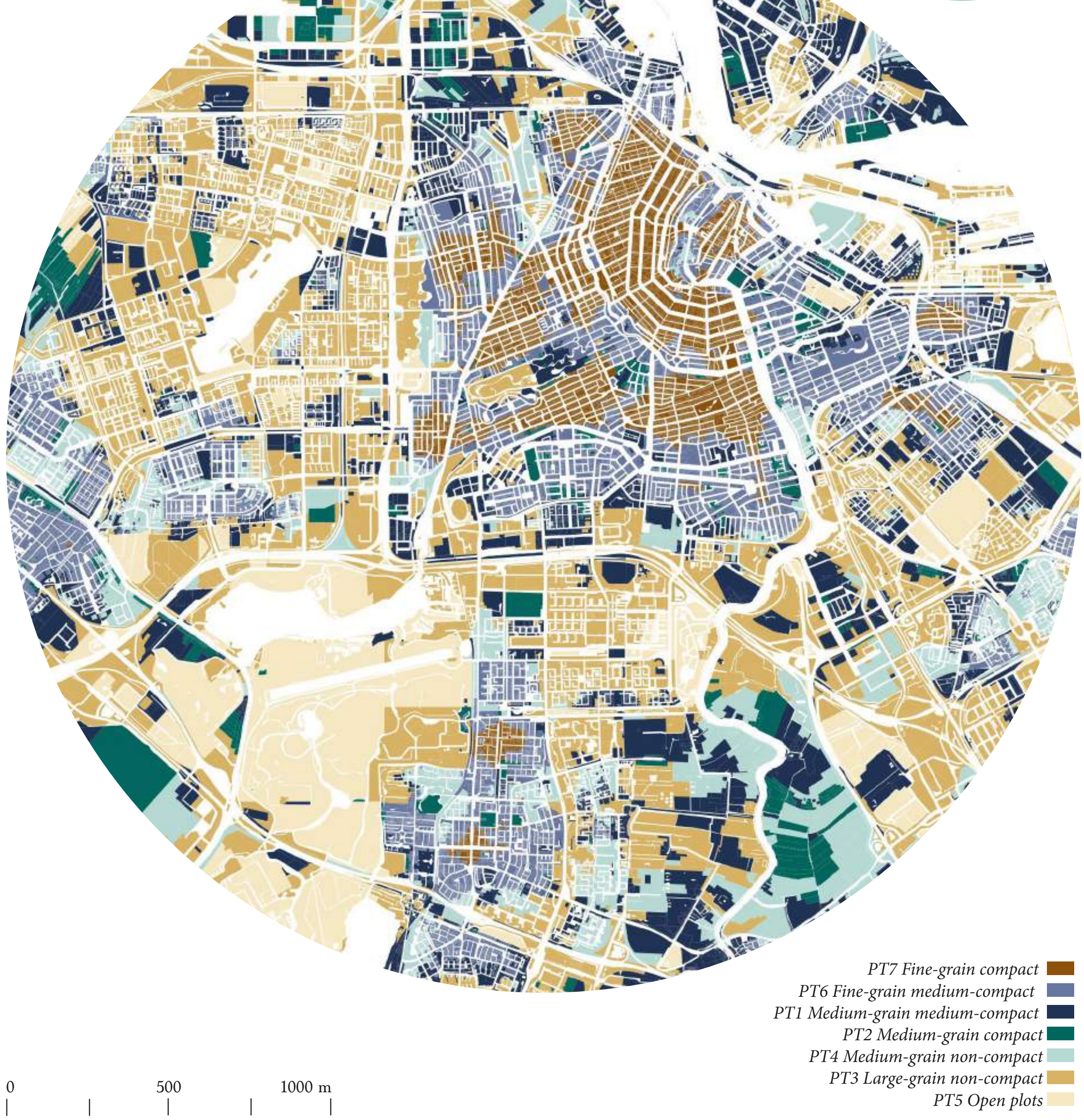


0 0,5 1 2 3 km

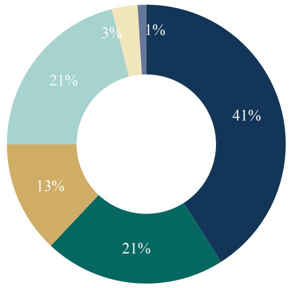
0 500 1000 m

Amsterdam

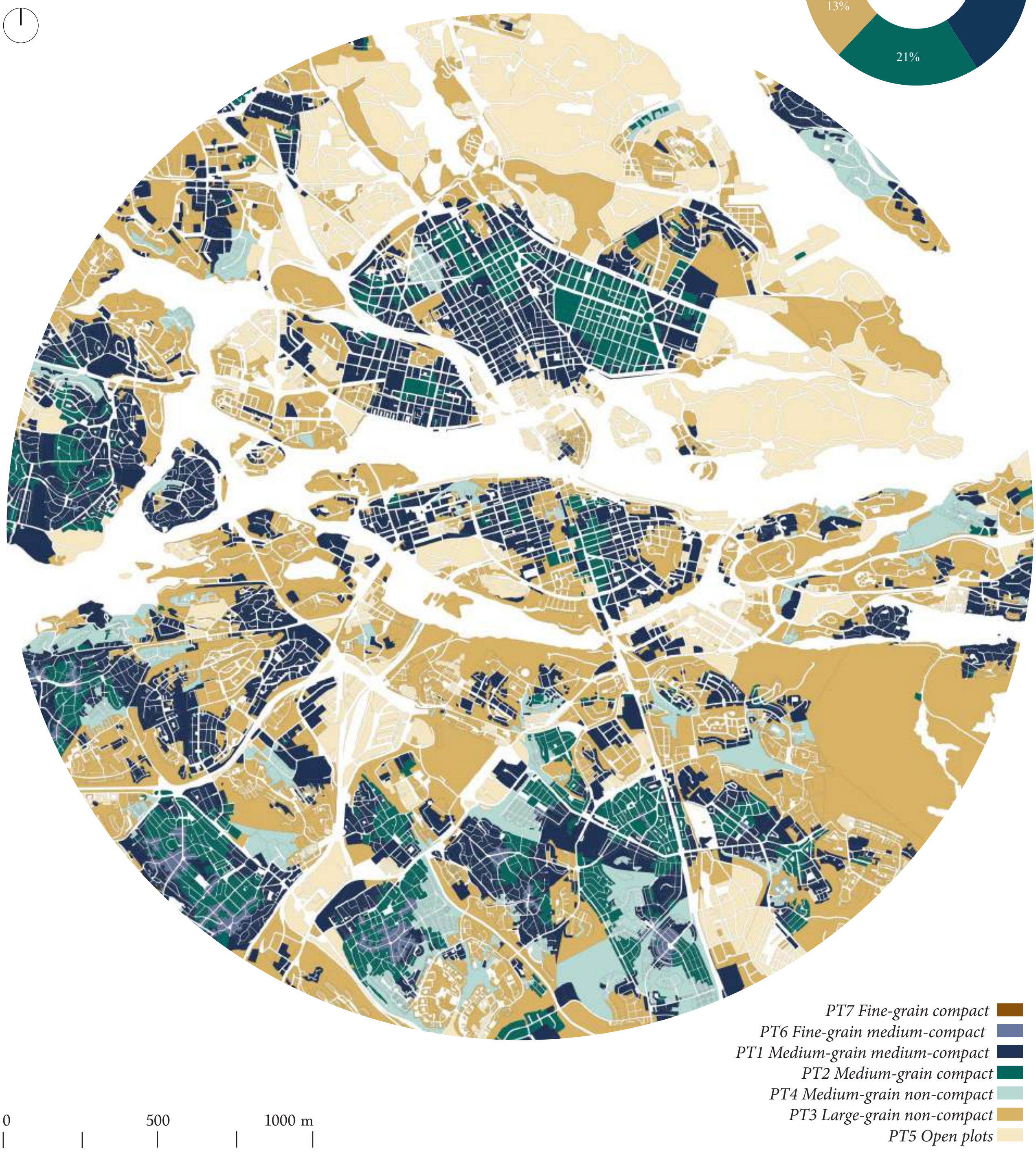

12%
19%
10%
10%
17%
1%
31%


0
0,5
1
2
3 km
PT7 Fine-grain compact
PT6 Fine-grain medium-compact
PT1 Medium-grain medium-compact
PT2 Medium-grain compact
PT4 Medium-grain non-compact
PT3 Large-grain non-compact
PT5 Open plots
0
500
1000 m

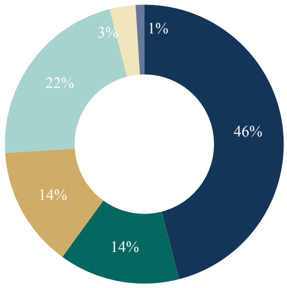
Stockholm



0 0,5 1 2 3 km



Gothenburg

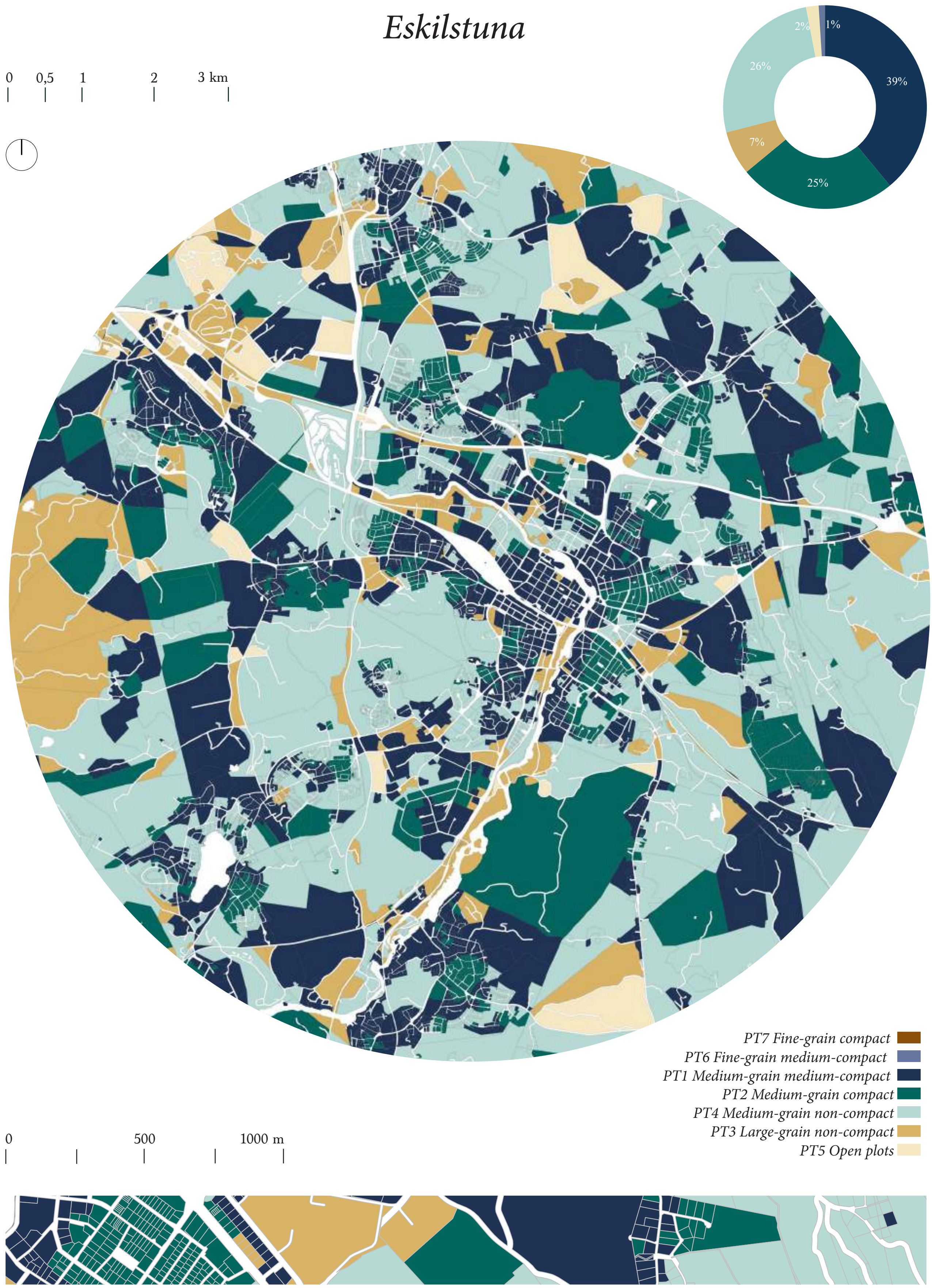


3%
1%
22%
46%
14%
14%

0
0,5
1
2
3 km
PT7 Fine-grain compact
PT6 Fine-grain medium-compact
PT1 Medium-grain medium-compact
PT2 Medium-grain compact
PT4 Medium-grain non-compact
PT3 Large-grain non-compact
PT5 Open plots

0
500
1000 m

Eskilstuna



0
0,5
1
2
3 km
2%
1%
26%
39%
7%
25%
PT7 Fine-grain compact
PT6 Fine-grain medium-compact
PT1 Medium-grain medium-compact
PT2 Medium-grain compact
PT4 Medium-grain non-compact
PT3 Large-grain non-compact
PT5 Open plots
0
500
1000 m

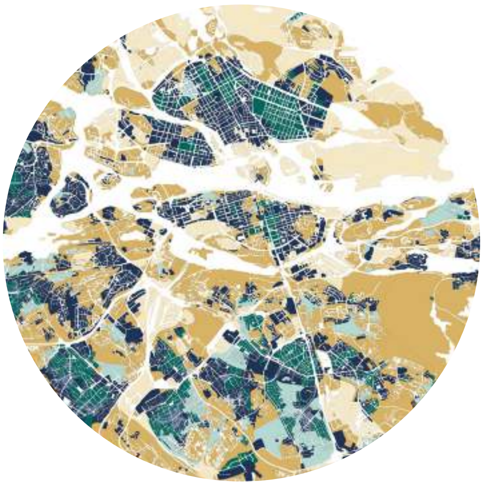
Five cities comparison

0 1 5km

London

Amsterdam

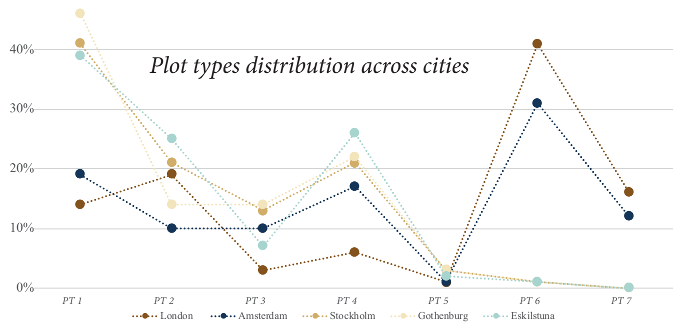
Stockholm



Gothenburg

Eskilstuna

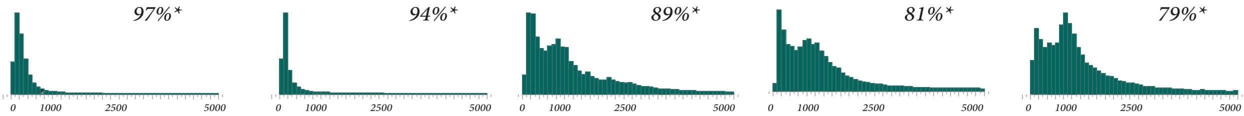
The Swedish cities are characterised by a dominance of the medium-grain plot types. In Amsterdam and London, the distribution of all seven urban types is more even, with a dominance of the fine-grain plot types.



Distributions

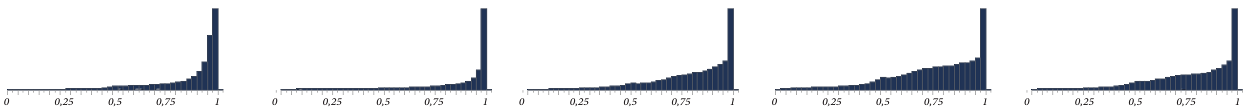
LONDON	AMSTERDAM	STOCKHOLM	GOTHENBURG	ESKILSTUNA
3411	*416,5*	*1084*	*733*	*72,5*
3069673	*579405*	*381878*	*303835*	*94731*

SIZE

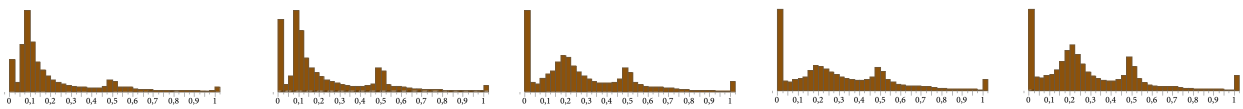


**For plot sizes observations higher than 5000sqm are removed from histograms, in order not to distort data with extra large plots.*
The number on the top shows percentage of observations lower than 5000sqm for each city.

COMPACTNESS INDEX



FRONTAGE INDEX



Section 6

Results

6. 1 Morphological measures of plots

The plot measures developed in this thesis have highlighted major similarities in the plot systems of the Swedish cities and differences from the patterns in Amsterdam and London. This is described below and shown in the Atlas of Plots.

When it comes to geometric measures, London and Amsterdam have more plots (in absolute terms) than the Swedish cities. On average, the London and Amsterdam plots are four to six times smaller than ones in Swedish cities (see also the distribution of the three geometric variables in the Figure 6.1). Moreover, the distributions of plot size demonstrate a striking difference between Swedish cities on the one hand and Amsterdam on the other. For example, the Swedish cities have a large share of plots of approximately 1000m^2 while Amsterdam and London are dominated by plots of approximately 200 m^2. Over 20% of plots in Swedish cities are larger than 5000m^2, while in London and Amsterdam this share is only 3% and 6% respectively.

The same difference can be seen when it comes to plot compactness; Amsterdam and London have more compact plots than the Swedish cities. Plot compactness in the Swedish cities varies, with plots more compact in Stockholm than Eskilstuna. This, plus the presence of extra-large plots, may be explained by the larger share of non-urbanised areas in the smaller city of Eskilstuna. These, in turn, are characterised by less compactly shaped plots. When it comes to the proportion of street frontage, London has plots with the smallest plot frontage index, followed by Amsterdam with slightly higher val-ues. In Swedish cities, plot frontages are, on average, larger with the highest frontage index found in Gothenburg.

FIG. 6.1 Distribution of three geometric measures across five cities

Interestingly, when examining the frontage index distribution, a

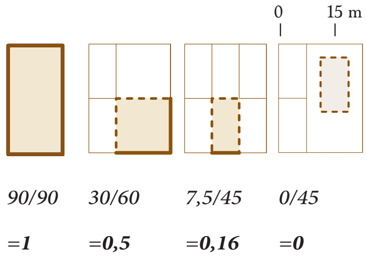


FIG. 6.2 Frontage index values allowing to distinct particular plots (from left to right: plots as blocks, corner plots, row plots, plots with no access to public space.

rather similar pattern can be found across all five cities. Firstly, there is a large share of zero values. This highlights the high presence of plots with no connection to street space. These plots are normally located in non-urbanised landscapes, but also post-war housing areas, as illustrated by Amsterdam (See figure 6.3). Two other ‘spikes’ in the distribution histograms demonstrate the frontage index typical of row plots in regular grids (index varies from 0.1 to 0.3) and also highlight the presence of corner plots (index = 0.5, see Figure 6.2).

FIG. 6.3 Example of plot systems layer in Amsterdam, demonstrating large share of plots with zero frontage index (in dark blue) and hence with no access to street space

Also, the descriptive statistics of the accessibility measures (See Atlas of Plots for descriptive statistics) show a striking difference between the Swedish cities and London and Amsterdam. Both London and Amsterdam have approximately five to six times more plots accessible within 500m walking distance than the Swedish cities. This becomes apparent when the accessible number of plots is visualised in the same range [26] for all five cities, as shown in Figure 6.4. Interestingly, the difference in distribution of accessible plots can also be seen in London and Amsterdam. While Amsterdam has the highest values in the city centre, in London the highest values for accessible number of plots are located outside the city core.

26. Ranging between 1 and 2574 accessible plots, that is maximum value for London

Further, on average, London has the most compact plots within 500m walking distance, compared to Amsterdam and the Swedish

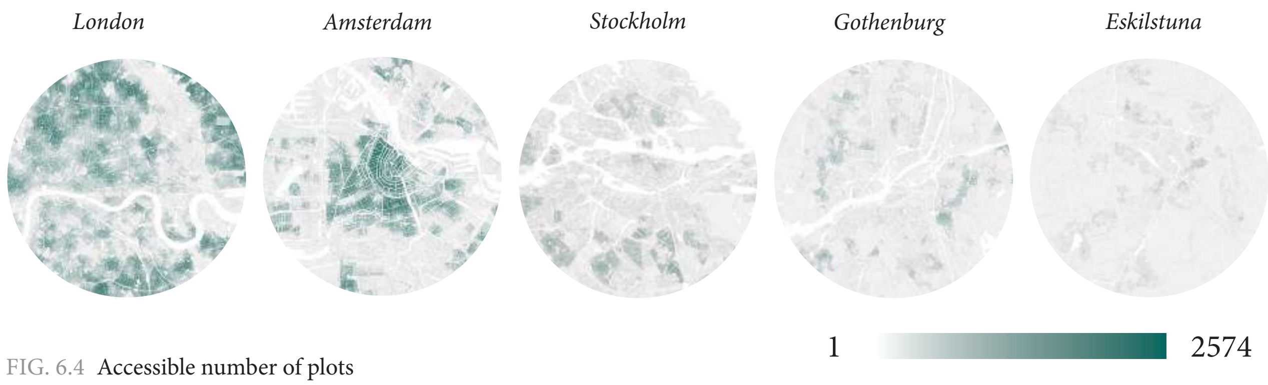


FIG. 6.4 Accessible number of plots visualised in the same range (from 1 to 2574 plots)

cities (which have rather similar values). Also, the accessible frontage index is, on average, lowest in London, followed by Amsterdam and then the Swedish cities.

6. 2 Seven analytical plot types

The data-driven classification of plots resulted in the following seven plot types (Bobkova et al., 2019a). The scatterplots demonstrate that, taken separately, the variables cannot capture the differences between types but that together, they contribute to their formation (See Figure 6.5).

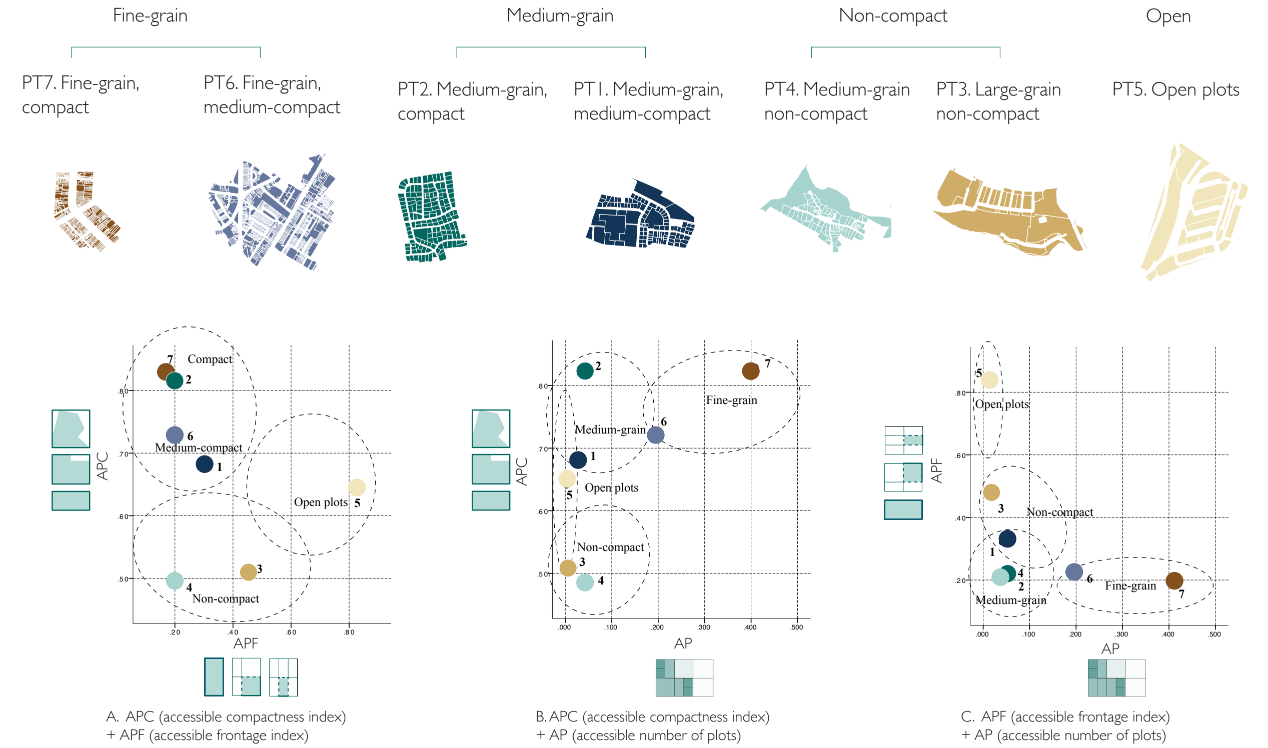


FIG. 6.5 Quantitative profile of seven types; type representatives with labels and three scatterplots. A. Accessible compactness index and accessible frontage index. B. Accessible compactness index and accessible number of plots. C. Accessible frontage index and accessible number of plots.

27. *The labels used to name the types are derived from the key morphological variable(s) used as input for the clustering: "grain" (fine-, medium- or large-) to describe the pattern of accessible number of plots and "compact" (non-compact, medium compact, compact) to describe the shape of plots; "open" to describe high value of frontage index.*

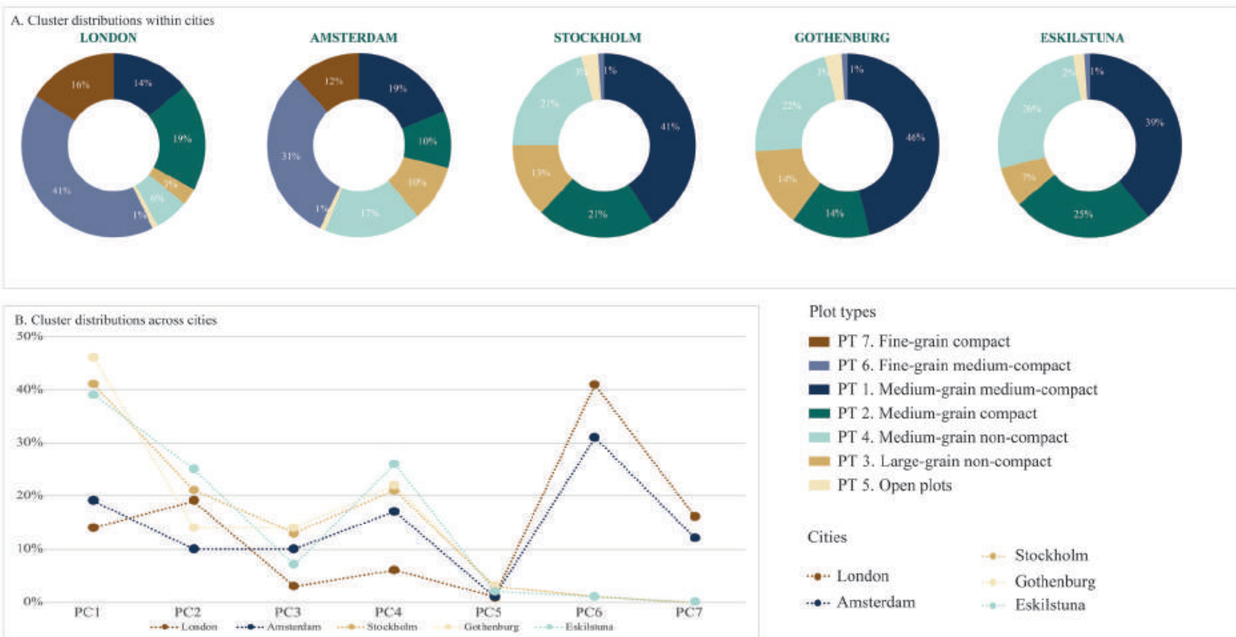
Two plot types that are distinct from the others in the values of all three variables are *the fine-grain compact type* (PT7) and *the fine-grain medium-compact type* (PT6) [27] . These may be characterised as having extremely high plot accessibility, high plot compactness and low frontage index values.

Next, two medium-grain plot types are defined (PT1 and PT2) that can be described as having average plot accessibility plus a relatively high accessible compactness index and low accessible frontage index values. These are labelled *medium-grain compact* (PT2) and *medium-grain medium-compact* (PT1) respectively, because PT2 can be distinguished by higher compactness values than PT1.

Further, we find two types (PT3 and PT4) characterised by having the lowest compactness index of all seven types. These can be described as non-compact types, with PT3 having lower plot accessibility than PT4. These two plots types are called *large-grain non-compact* (PT3) and *medium-grain non-compact* (PT4) respectively.

Finally, there is one type (PT5) that stands apart from the others and features the highest plot frontage index. In other words, this type groups the plots with the highest proportion of street front,

FIG. 6.6 Frequencies of types within (A) and across (B) cities.

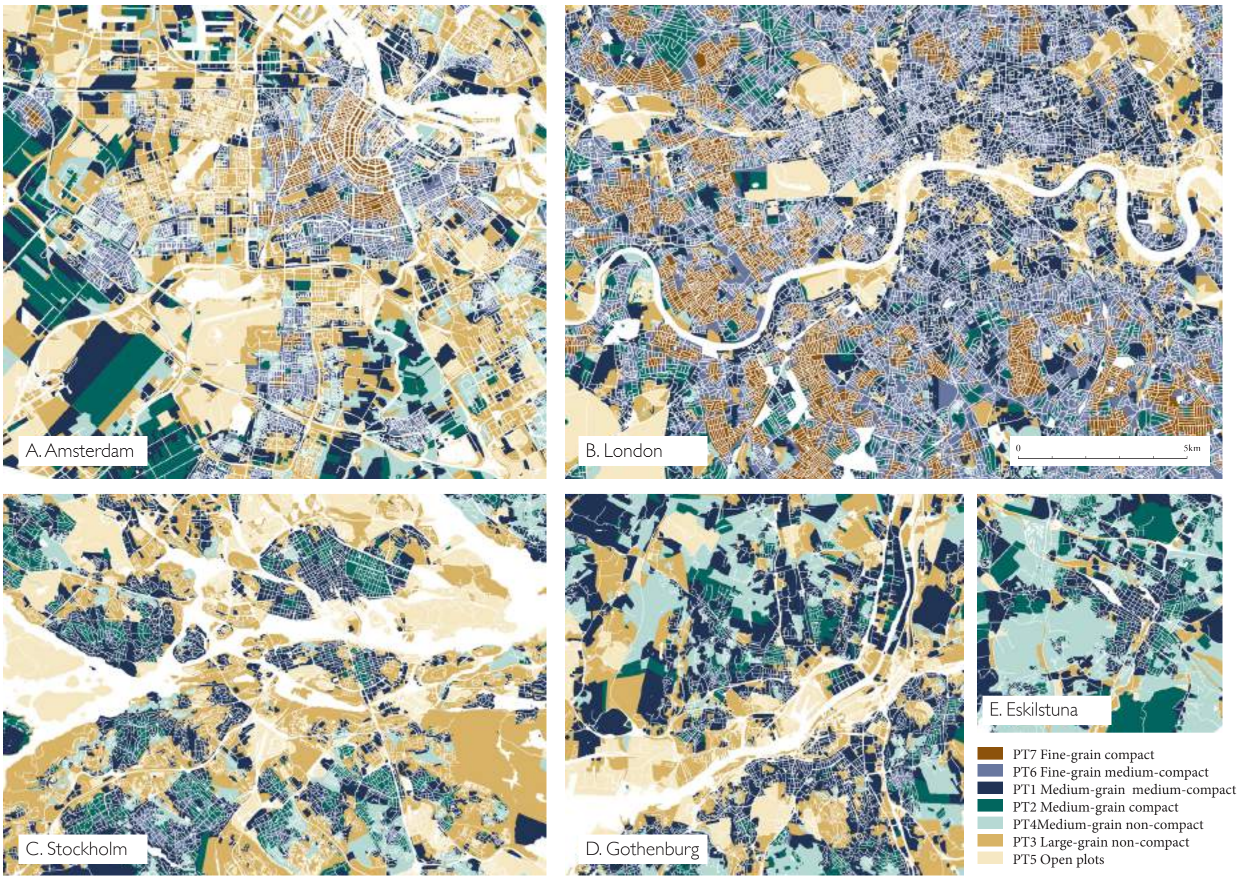


and commonly comprises a single urban block surrounded on all sides by streets. This type is called *open plots*.

The quantitative distribution of types within and across cities shows strong similarities in the three Swedish cities and major differences to London and Amsterdam (Figure 6.6). The Swedish cities can be characterised by a dominance of the two medium-grain plot types (PT1 and PT2) while, in Amsterdam and London, the distribution of all seven urban types is more even, with a dominance of the fine-grain plot types (PT6 and PT7). Interestingly, these plot types are only found in London and Amsterdam.

The spatial distribution of the seven types in five cities shows several distinctive patterns worth highlighting (Figure 6.7). The most compact and smallest plot types (PT7 and PT6), are prominent in Amsterdam and London. In Amsterdam they gravitate towards the city centres, supporting Webster and Lai's (2003) notion that central plot systems normally become smaller towards central locations in cities. However, this is not the case in

FIG. 6.7 Spatial distribution of types in five cities. A. Amsterdam. B. London. C. Stockholm. D. Gothenburg. E. Eskilstuna



London, where the finest plot types are not found in the City of London but identify local centres of boroughs. In the Swedish cities, a similar tendency to Amsterdam can be found, where medium-grain plot types (PT1 and PT2) highlight the city centres. At the same time, in Stockholm and Gothenburg, these plot types also represent villa areas located in the periphery.

Further, we can observe belts formed by irregular plot shapes (PT3) in combination with open plots (PT5) around the city cores in Amsterdam, Stockholm and Gothenburg. Thus, these two plot types are typical of urban fringe belts formed at the edge of urban areas in periods of slow urban growth which, once growth resumed, became embedded within the urban fabric (Hopkins, 2012).

6. 3 **Empirical validation of theories (results of statistical analysis)**

The validity of the quantitative descriptions of plots developed within the scope of this thesis has been partly tested in Papers 4 and 5, following the method described in Section 5. In Paper 4, the performance of plot types was tested against the concentration of economic activities in cities.

The statistical analysis demonstrated that fine-grain and more compact plots with small frontage ratios, such as PT7 and PT6 in London and Amsterdam (Figure 5, brown and light blue) and PT1 and PT2 in Stockholm (dark blue and dark green), were associated with the highest concentration of economic activity. This contrasted with large-grain and non-compact plot types, such as PT3 and PT5 (See Figure 6.8).

We also found that compact types performed slightly better than non-compact types of similar grain size (by comparing PT7 to PT6 in Amsterdam and London and PT2 and PT4 in London and Stockholm). These findings support our hypothesis that not only size but also the degree of plot compactness contributes to the concentration of economic activity in cities.

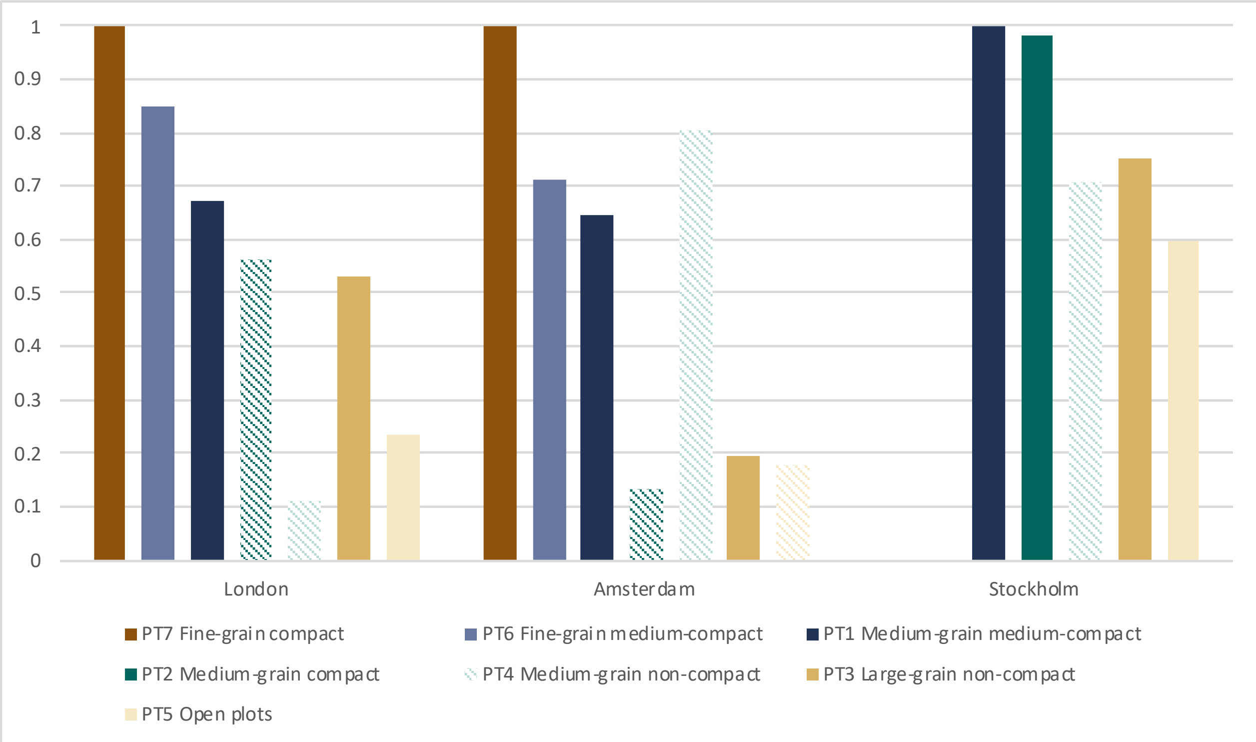


FIG. 6.8 Summary of statistical analysis of differences between the plot types, in terms of distribution of economic activity. The bar charts show mean rank values for each sub-model. "Mean rank" is a relative value and, in order to compare the results between cities, is rescaled to range from 0 to 1. If a particular plot type covers less than 5% of observations within the sub-model, it is shown as a dashed bar.

Next, we compared the plot types characterised by different degrees of plot frontage, but with relatively similar grain size and compactness. This comprised PT3 and PT5 (See Figure 6.8), where the latter has the highest frontage ratio. In London and Stockholm, plots with the lowest frontage ratio (PT3) were generally associated with higher concentrations of economic activity when compared to PT5.

To summarise, the results of the statistical analysis supported our initial hypothesis that plots of smaller size, more regular shape and smaller frontage generally correspond to higher concentrations of economic activities in cities.

In Paper 5, we tested the hypothesis of whether there is a relation between the accessible number of plots and the diversity of economic activity. More precisely, whether a higher number of plots and thus also smaller plot sizes, is associated with greater diversity of economic activity.

Although the data set here was fairly small, the statistical analysis indicated two things. Firstly, we found a positive correlation between accessibility to plots and diversity of economic activity. In other words, locations with a higher number of plots within a 500-meter range have a greater diversity of economic activity. Secondly, when general diversity is correlated with accessibility to plots, the correlation generally increases with greater radii, whereas when retail diversity is correlated with accessibility to plots, the correlation generally increases with smaller radii. Thus, the plot system (measured as accessible number of plots) affects the two different types of diversity (general diversity and retail diversity), but on different scales.

Locations with greater accessibility to plots within a larger radius (2500m) correlate with a greater diversity across a broad range of economic activity (such as retail, banking and hotels, what we refer to as general diversity), while locations with greater accessibility to plots within a smaller radius (500m) correlate with greater diversity across a narrower range of economic activity (retail diversity).

By mapping the residuals from the linear regression analysis, it was found that retail diversity in some areas cannot be explained by the higher number of plots in the area. This may be due to the absence of some important variables in the model, but we suggested in the paper that there may be a necessity to introduce diversity measured on an even finer scale, using a categorisation within one kind of retail: for instance, within 'fashion' category.

Section 7

Discussion

7. 1 General conclusions: theoretical and methodological advancements

The overarching purpose of the PhD thesis has been to develop a robust scientific framework for what we call the 'theory of natural occupation', by which the long-term evolution of cities is understood to be aligned with a process of economic diversification expressed in increasing sub-divisions of property rights, especially for land where it also takes the form of more fine-grained plot systems. As a broader theoretical foundation, it used Webster and Lai's institutional theory of urban development (see Section 2, and Papers 1, 2 and 4) which, in this thesis, is connected to a set of theories and concepts originating in urban morphology. These highlight the importance of shape and structure of plot systems in creating the conditions for urban diversity and for the temporal evolution of built form (Section 3 and Papers 1 and 2).

In support of this, a more specific objective of the thesis has been to develop stringent quantitative descriptions of the geometry and configuration of plot systems, in the form of both individual measures and typologies. This is built on a generic method of representing plot systems, independent of the particular legal systems and cartography of different countries. On the one hand, it is based on Scheer's minimalist definition of the plot (Scheer, 2018) and, on the other, Hillier's generic function concept (1996), as discussed in Sections 5.1 and 6.2.

The three measures of plots developed for this purpose are conceptualised as 'plots in space', 'plots in time' and 'plots as interface' (Section 3). Based on these three measures, plot types have been generated that enabled us to identify particular plot types in cities in which these three measures can be found in specific combinations. This also opens the way for comparisons between cities (Paper 3). The method of representation, measures and generated plot types have shown to be informative in describing similarities and differences within the five selected European cities. For example, it was found that Amsterdam and London may be characterised by much finer grain plot patterns, not found in Swedish cities. Further, irregularly shaped (non-compact) plots and open plots form distinct fringe belts in Amsterdam and the Swedish cities.

Finally, our purpose was to apply these descriptions and develop a better understanding of the relation between the form of plot systems and economic processes in cities, whilst testing the theory of natural occupation. This was done through empirical tests that demonstrated how the shape and structure of plot systems are, indeed, related to the spatial distribution of economic activities in cities (Paper 4) and to their diversity (Paper 5). More precisely, we were able to demonstrate that the generated plot types clearly differed in performance in this respect; plot types of smaller size, more regular shape and smaller frontage are associated with higher concentrations of economic activities. It was also indicated (albeit weakly, due to the smaller sample size) that accessibility to plots is associated with greater diversity of economic activities.

In other words, through the enhanced means of describing plot systems developed in this thesis, we have been able to increase the spatial understanding of economic theories, such as the one presented by Webster and Lai (2003). On a more general plane, this also demonstrates the need for morphological support in institutional studies of urban development.

In summary, we see the theoretical and methodological advancements described above as important contributions to academia, particularly in the field of urban morphology but also in other fields which study property rights, land use regulations and plot systems. These include urban planning, urban economics and urban geography, as further discussed in Section 7.2. Furthermore, the empirical studies that supported a direct relation between the shape and structure of plot systems and economic processes in cities are an important contribution to urban design and planning practice, as will be discussed in Section 7.3.

7. 2 **Reflections and directions of future research**

7.2.1. Further testing of theory

The main focus of this thesis was the development of quantitative descriptions of plot systems, that could help us to further test the theory of natural occupation. This, in turn, would enable us to operationalise important concepts; relating plot systems to such urban processes as diversity of economic activity and the temporal transformation of urban fabric.

The steps towards testing these concepts were made in Papers 4 and 5, which tested concentration and diversity of economic activity respectively. Quantifying the concentration of economic activity is relatively straightforward, but urban diversity carries a need for further methodological developments. This is because the concept of diversity is not just quantitative but (in this case of economic activity in cities) involves qualitatively assessed classification (Bobkova et al., 2017a; Marcus and Bobkova, 2019). These methodological problems relating to urban diversity were discussed extensively in Paper 5. The discussion included the need to reflect on the degree of resolution included in the diversity calculation when classifying economic activity, plus the fact that urban diversity is dependent on the spatial reach of different locations. Thus, areas with only local reach may present high diversity in specialised economic activity, but low diversity in the case of broad economic activity.

Paper 5 provided a first study and produced preliminary results supporting our initial hypothesis about the relation between the morphology of plot systems and diversity of economic activity. However, we also learnt how a study of this kind needs further data preparation if it is to properly address this particular hypothesis, both when categorising economic activity and when defining the scale of the analysis. Therefore, our empirical study allowed us to highlight general methodological issues related to both quantitative measures and theoretical definitions of urban diversity; interesting subjects to address in future studies.

Another aspect of the theory of natural occupation discussed in this thesis is the study of temporal transformations of the urban fabric originating in Conzenian studies. This is one of the central notions in urban morphology. Studies of temporal transformations were beyond the scope of this thesis because they require plot datasets from different historical periods. This kind of data (historical ownership patterns or property maps) is normally much harder to extract compared to, say, street networks or building patterns, especially if it covers whole city regions and not just selected neighbourhoods. Nevertheless, we found that it would be very useful to conduct such longitudinal studies of plot systems; they could strongly underpin a better understanding of the role of plots and plot systems, in terms of both urban diversification over time and the more general historical evolution of cities.

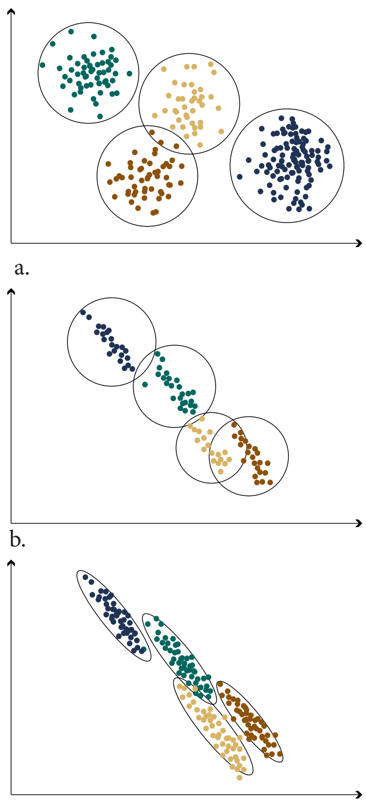
Finally, as mentioned in the introduction, this thesis was limited to studying the morphological dimensions of plot systems and did not consider the impact of land-use regulations (something which could be added in future studies).

7.2.2. Adding more study areas

This thesis has developed quantitative descriptions of plot systems for European five cities, which enabled us to acquire an understanding of plot systems within the context of western and northern Europe. However, we recognise that the study could be extended by adding more cities, including different geographic contexts such as American, Asian and African. Further, it would be interesting to include cities developed within different planning traditions, such as cities in former Socialist block countries or, as Kropf points out, cities where the legal dimension is convoluted or not clearly defined, as in Mongolia (Kropf, 2019, p. 3).

7.2.3. *Methodological challenges and new developments*

In this thesis, we used k-means cluster analysis to develop the plot types, because it allows us to deal with large datasets and affords the capability to handle continuous variables (see Section 5.4). However, there are also other clustering methods that could have been used and although "there is no absolutely right way to do categorisation" (Wilson, 2000, p. 8), we wanted to highlight some of the sensitivities of the methodological choice made in this thesis. Firstly, the choice of k-means clustering in relation to the shape of the data distribution; secondly, the difficulties related to the number of clusters; and thirdly, the choice of what is called 'hard classification'. It would therefore be interesting to explore other, often more advanced methods of spatial data classifications and compare them with, say, k-means, the method most often used in recent morphological studies (such as Gil et al., 2012; Serra, 2013) and the one applied in this thesis. We will shortly discuss these three issues and possible directions for future exploration.



a. b. c.

FIG. 7.1 Difference between k-means (a,b) and GMM cluster analyses (c).

K-means is sensitive to variance and better at clustering data that is more circular than very oblong clusters (see Figure 7.1). Other methods exist, such as Gaussian Mixture Models (GMM clustering), that generally work like k-means but account for variance (in other words, the shape of the distribution (Bishop, 2006).

In k-means, the number of clusters is not given, and validity indices are used to find the optimal number. We used silhouette analysis to derive the optimal number of clusters. This is one of many validity indices available for this purpose and a review of 20 cluster validity indices has shown it to achieve the best overall results (Arbelaitz et al., 2013). Another way to select the optimal number of plot types would be to test different cluster solutions, in terms of how well they explain the distribution of economic activity or other relevant urban processes. However, this would result in highly specific typologies developed for one purpose; economic activity, in the example given here.

The choice of hard classification is not related to k-means but is raised here because it could be another way of dealing with the two issues discussed above. The difference between 'hard' and ´soft´ (or 'fuzzy') clustering is that in hard clustering, each observation belongs to only one cluster, while in soft clustering, the observation gets a percentage of belonging. This would allow us to define archetypes, or 'strong' types, that belong primarily to one cluster, but also in-between types that share the characteristics of two or even three clusters. A high number of in-between types is an indication that the number of clusters should be increased.

It is important to reiterate that there is no one perfectly right way to conduct statistical cluster analysis, because each method has its own limitations. Also, in contemporary data science, these methods are constantly advancing and allow us to develop not entirely different, but richer, statistical models. The final choice and its interpretation always depend on the purpose and research question at hand.

When it comes to the analysis of co-variation between the morphological measures and, say, measures of urban diversity, the statistical models could be further developed by including additional tests for any problems with spatial autocorrelation of the dependent variables. Spatial autocorrelation is a general issue with spatial data, in which geographically near locations show similar values of a certain measure. Particular to the measures used in this thesis (and related to spatial autocorrelation) is the use of accessibility measures in which observations that are in close geographical proximity will always have close values. This highlights the need to extend the autocorrelation tests.

The issues raised here would be an interesting extension of the study of plot types and would ideally be conducted in close collaboration with a data science specialist.

7. 3 **Contribution to academia and field of urban morphology**

As one of the three central components of urban form, plots and plot systems are described as the 'problem child of urban morphology'. This is due to their dual nature, bridging the city as an institutional entity and the city as a physical entity; a fact which has delayed the development of rigorous descriptions. This is significant because, as pointed out by Scheer (2018), if something is "to be useful for subjective observation, it must be converted into objective information – accurate, measured, and recorded" (p.163).

The morphological descriptions of plots and plot systems developed in this thesis, using a morphological approach that was independent of their legal dimension, allowed us to make international comparisons. However, it also broke new ground for studies of urban contexts in which the legal dimension of plot systems is convoluted, or not clearly defined. Kropf argues that this is important, because there are many different kinds of human settlements, including those where, "1) there is no private property, such as in China; 2) there is a very different system of traditional, customary land rights, such as in pre-colonial Africa; or 3) there is a mixture of private property and customary systems, such as in present-day Mongolia" (Kropf, 2019, p. 3).

The development of quantitative descriptions of plot systems introduced in this thesis, as both measures and types, breaks new ground for multiple research directions in urban morphology, be they empirical studies, historical studies, or cross-cultural comparisons where plot systems can be studied in isolation or in combination with other components of urban form.

A case in point is the testing of the burgage cycle concept (Conzen, 1960). This was beyond the scope of this thesis, but a parallel project by Berghauser Pont et al. (2019) specifically examined it by applying the plot types developed in this thesis. They (ibid.) studied plot types in combination with building types, defined by their built density and land coverage. According to the burgage cycle concept, a more fine-grain subdivision of plots is aligned with both higher built density and higher land coverage (Conzen, 1960), as confirmed by Berghauser Pont et al. (2019). However, that study analysed the relation between plot and building types without taking time into consideration, whereas the burgage cycle concept concerns the temporal transformation of the urban fabric. To truly test the concept therefore requires longitudinal studies; an interesting direction for further research.

7. 4 **Contribution to practice and field of urban planning and design**

As discussed repeatedly in this thesis, the role of plots (and in particular how plot size can create the conditions for urban diversity) is recognised in academia, yet we still find deficits in its implementation in practical urban planning and design. This is discussed in Paper 2 (Bobkova et al., 2017b).

In the discussion on creating more sustainable cities, UN Habitat (2014) developed guidelines in which mixed-use and socio-economic diversity are crucial for urban environments. Also, in Swedish planning practice, there is often a central aim of creating the conditions for mixed-use and diversity. However, this is mostly achieved through institutional instruments, such as land use regulations. On the other hand, morphological instruments, such as the design of plot systems, are often overlooked. This is where plot types and measures become operative, because they potentially allow to translate the desired outcome (for instance, economically diverse neighbourhood) into numeric indicators that represent particular urban plot pattern and hence serve as the concrete design guidelines for urban planners and designers, along with, for example, desired building density indicators, established street profiles or the like.

A better understanding of the relation between the shape and structure of plot systems and the distribution of socio-economic diversity in cities (which, it is hoped, this thesis has provided) allows planners, architects and developers to create the spatial conditions for urban diversity. Moreover, it opens the way to better-informed maintenance and management of existing areas in which the shape and structure of plot systems need to be managed and adapted over time, as cities grow and develop.

This raises the question of how the layer of plots is used and managed in current planning practice and what difference new knowledge (as provided by this thesis, for example) would make. Hence, another interesting extension of this thesis would be to study how the layer of land plots is used in current real estate/urban development practice and to outline possible implementation deficits of such practice.

Section 8

Summary of the papers

8. 1 **Multivariable measures of plot systems: describing the potential link between urban diversity and spatial form based on the spatial capacity concept. (Paper 1)**

Authors: Evgeniya Bobkova, Lars Marcus, Meta Berghauser Pont

Published in: Proceedings of the 11th Space Syntax Symposium, Lisbon, 2017; Vol. 47, pp. 1–47.

Summary: Urban diversity is a widely recognised concept used to describe vitality in cities. It is often associated with cities that perform successfully from both an economic and social perspective. This paper investigates the concept of spatial capacity; in other words, the impact of plot systems (land division) on urban diversity. The aim of the paper is to identify fundamental variables of plots that could potentially contribute to urban diversity and socio-economic performativity. Four measures are proposed: 1) accessible number of plots, 2) plot size diversity, 3) plot compactness index and 4) plot frontage index. The concept of location-based measures (as opposed to area-based measures) is used to define three variables. In the second part of the paper, these variables are tested in a few neighbourhoods in Stockholm in order to demonstrate similarities and differences between them. In the later tests, the measure of plot size diversity introduced in the paper failed to give informative results. It was therefore abandoned in subsequent stages of the PhD thesis.

Keywords: Urban diversity, plot systems, spatial capacity, area-based measures, location-based measures .

Authors contribution: Conceptualisation: E.B., L.M., M.B.P. Methodology: E.B., M.B.P. Spatial analysis: E.B. Writing (original draft preparation): E. B. Writing (review and editing): L.M., M.B.P.

Visualisation: E.B. Supervision: L.M., M.B.P.

8. 2 **Plot systems and property rights: morphological, juridical and economic aspects. (Paper 2)**

Authors: Evgeniya Bobkova, Lars Marcus, Meta Berghauser Pont

Published in: 4th ISUF International Conference Proceedings. City and territory in the Globalisation Age, Valencia, 2017, pp.177-185

Summary: Plots and plot systems, with their inherent duality of being both morphological and institutional entities, have an unusual number of relations with other academic fields. Based on this proposition, the second paper connects central morphological theories of plots to relevant concepts in related disciplines, such as legal geography, urban planning and design and real estate development. The entanglements of the morphological, legal and economic definitions of the term are discussed, so as to better address and compare the vital layer of plot systems in different urban contexts and identify common fundamental aspects of the notion of plot systems.

Keywords: plot systems, exclusive property rights, land ownership, spatial capacity, real estate development, urban design.

Authors contribution: Conceptualisation, E.B., L.M. Writing (original draft preparation): E. B. Writing (review and editing): L.M., M.B.P. Supervision: L.M., M.B.P.

8. 3 **Towards analytical typologies of plot systems: quantitative profile of five European cities. (Paper 3)**

Authors: Evgeniya Bobkova, Meta Berghauser Pont, Lars Marcus

Published in: 'Environment and Planning B'. 0 (0), 1–17. https://doi.org/10.1177/2399808319880902

Summary: The third paper discusses the existing knowledge gaps in typological descriptions of plot systems and proposes a data-driven classification of plot systems, based on the three morphological measures introduced in Paper 1. It introduces a methodology for developing such analytic plot types and presents the resulting plot typologies, based on data from five European cities. This generates seven plot types that allow us to determine the differences between, and within, these cities in terms of their plot patterns. Finally, the advantages of the developed types are highlighted. For example, their capability to describe and compare plots in various cities overall and the possibility of discovering new plot patterns in cities and relating them to commonly recognised ones.

Keywords: plot systems, typologies, configurational measures, k-means cluster analysis, data-driven classification.

Authors contribution: Conceptualisation, E.B., M.B.P. Methodology, E.B., M.B.P. Spatial and statistical analysis: E.B. Results validation: E.B. Writing (original draft preparation): E. B. Writing (review and editing): L.M., M.B.P. Visualisation: E.B. Supervision: L.M., M.B.P.

8. 4 **Structure of plot systems and economic activity in cities: linking plot types to retail and food services in London, Amsterdam and Stockholm. (Paper 4)**

Authors: Evgeniya Bobkova, Lars Marcus, Meta Berghauser Pont, Ioanna Stavroulaki, David Bolin

Published in: 'Urban Science', 3, 66. https://doi.org/10.3390/urbansci3030066

Summary: Paper 4 presents the results of the empirical testing of the plot types developed in Paper 3 against the concentration of economic activities in three European cities (London, Amsterdam, Stockholm). The study is positioned within the broader framework of urban development theory, which argues that the process of urbanisation is aligned with increased subdivision of property rights, (in other words, plots) due to the process of economic specialisation. While the concept of economic specialisation includes aspects of higher concentration of economic activity (how many) and their diversification (how different), this paper explores only the first aspect (concentration). The results of the study provide empirical support for our initial hypothesis that plots of smaller size, more regular shape and smaller frontage generally correspond to a higher concentration of economic activities in cities.

Keywords: plot systems; plot types; spatial morphology; property rights; economic activity; economic specialisation

Authors contribution: Conceptualisation, E.B., L.M., M.B.P., I.S. Methodology, E.B., L.M., M.B.P., I.S, D.B. Spatial and statistical analysis: E.B., D.B. Results validation: D.B. Writing (original draft preparation): E. B. Writing (review and editing): L.M., M.B.P., I.S. Visualisation: E.B. Supervision: L.M., M.B.P., I.S.

8. 5 **Spatial configuration of plot systems and urban diversity: empirical support for a differentiation variable in spatial morphology. (Paper 5)**

Authors: Lars Marcus, Evgeniya Bobkova

Published in: Proceedings of the 12th Space Syntax Symposium, Beijing, 2019.

Summary: This paper discusses the relation between plot systems (in particular, accessible number of plots) and urban diversity, starting with an overview of the complex issues behind the concept of diversity, and with particular focus on categorising economic activities and scale of diversity. Only Stockholm is used as a case study in this paper. Its results provide empirical support for our initial hypothesis showing a positive correlation between the accessible number of plots and diversity of economic activity (measured as diversity of retail services) and thus supports the theory of natural occupation.

Keywords: Spatial configuration, Plot systems, differentiation, diversity, economic activity

Authors contribution: Conceptualisation, L.M., E.B.; Methodology, L.M., E.B. Spatial and statistical analysis: E.B. Writing (original draft preparation) L.M., E.B. Writing (review and editing): E.B. Visualisation: E.B. Supervision: L.M.

References

Adams, D., Disberry, A., Hutchison, N., Munjoma, T., 2002. Land Policy and Urban Renaissance: The Impact of Ownership Constraints in Four British Cities. Planning Theory & Practice 3, 195–217. https://doi.org/10.1080/14649350220150044

Adams, D., Teisdell, S., White, J., 2013. Smart Parcelization and Place Diversity: Reconciling Real Estate and Urban Design Priorities. Journal of Urban Design 18, 469–477.

Alchian, A., Demsetz, H., 1973. The Property Right Paradigm. The Journal of Economic History 33, 16–27.

Alonso de Andrade, P., Berghauser Pont, M., Amorim, L., 2018. Development of a Measure of Permeability between Private and Public Space. Urban Science 2, 87. https://doi.org/10.3390/urbansci2030087

Arbelaitz, O., Gurrutxaga, I., Muguerza, J., Pérez, J.M., Perona, I., 2013. An extensive comparative study of cluster validity indices. Pattern Recognition 46, 243–256. https://doi.org/10.1016/j.patcog.2012.07.021

Asabere, P., Harvey, B., 1985. Factors influencing the value of urban land: evidence from Halifax-Dartmouth. Canada Real Estate Economics 13, 361–377.

Asami, Y., 1995. Evaluation of the shape of residential lots in landreadjustment projects. Regional Science and Urban Economics 25, 483–503.

Asami, Y., Niwa, Y., 2008. Typical lots for detached houses and lot shape analysis. Regional Science and Urban Economics 38, 424–437.

Babie, P., 2013. The Spatial: A Forgotten dimension of Property. Diego Law Review 50.

Barbour, G., Romice, O., Porta, S., 2016. Sustainable plot-based urban regeneration and traditional master planning practice in. Glasgow. Open House International 41, 15–22.

Barthelemy, M., 2017. From paths to blocks: New measures for street patterns. Environment and Planning B: Urban Analytics and City Science 44, 256–271. https://doi.org/10.1177/0265813515599982

Batty, M., 2018. Inventing future cities. MIT Press, Cambridge, MA.

Batty, M., 2009. Urban modelling. International Encyclopedia of Human Geography 51–58.

Berghauser Pont, M., Haupt, P., 2010. Spacematrix. NAi Publishers, Rotterdam.

Berghauser Pont, M., Marcus, L., 2015a. What can typology explain that configuration can not?, in: SSS10 Proceedings of the 10th International Space Syntax Symposium. The UCL Bartlett, London, pp. 2–43.

Berghauser Pont, M., Marcus, L., 2015b. Connectivity, density and built form: integrating ´Spacemate´ with space syntax. In I. "Sapienza" University of Rome, in: ISUF. Sapienza" University of, Rome.

Berghauser Pont, M., Marcus, L., 2014. Innovations in measuring density: from area and location density to accessible and perceived density. Nordic Journal of Architectural Research 2, 11–31.

Berghauser Pont, M., Marcus, L., Stavroulaki, G., Gil, J., Serra, M., Bobkova, E., 2019. The spatial distribution and frequency of street, plot and building types, across five cities identifying common as well as unique traits. Environment and Planning B 46, 1226–1242.

Berghauser Pont, M., Olsson, J., 2017. Typology based on three density variables central to Spacematrix using cluster analysis., in:

XXIV International Seminar of Urban Form. Valencia.

Berghauser Pont, M., Stavroulaki, G., Marcus, L., in press. Development of Urban Types, based on Network Centrality and Built Density, and their Impact on Pedestrian Movement. Environment and Planning B. https://doi.org/10.1177/2399808319852632

Berghauser Pont, M., Stavroulaki, I., Sun, K., Abshirini, E., Olsson, J., Marcus, L., 2017. Quantitative comparison of the distribution of densities in three Swedish cities, in: Proceedings ISUF 2017 XXIV International Conference: City and Territory in the Globalization Age. Editorial Universitat Politècnica de València, Valencia.

Bhat, C., Handy, S., Kockelman, K., Mahmassani, H., Chen, Q., Weston, L., 2000. Urban accessibility index: literature review. Cent. Transp. Res. Univ. Tex. Austin Spring.

Bishop, C.M., 2006. Pattern recognition and machine learning, Information science and statistics. Springer, New York.

Blomley, N., 1997. Property, Pluralism and the Gentrification Frontier. Canadian journal of law and society 12, 187–218. https://doi.org/10.1017/S082932010000541X

Bobkova, E., Bergauser Pont, M., Marcus, L., 2019a. Towards analytical typologies of plot systems: quantitative profile of five European cities. Environment and Planning B 0, 1–17. https://doi.org/10.1177/2399808319880902

Bobkova, E., Marcus, L., Bergauser Pont, M., Stavroulaki, I., Bolin, D., 2019b. Structure of Plot Systems and Economic Activity in Cities: Linking Plot Types to Retail and Food Services in London, Amsterdam and Stockholm. Urban Science 3, 66. https://doi.org/10.3390/urbansci3030066

Bobkova, E., Marcus, L., Berghauser Pont, M., 2017a. Multivariable measures of plot systems: describing the potential link between urban diversity and spatial form based on the spatial capacity concept, in: 11th Space Syntax Symposium. Instituto Superior Técnico, Lisbon, pp. 1–47.

Bobkova, E., Marcus, L., Berghauser Pont, M., 2017b. Plot systems and property rights: morphological, juridical and economic aspects., in: XXIV International Seminar of Urban Form. Valencia.

Buitelaar, E., 2003. Neither market nor government: Comparing the performance of user rights regimes. Town Planning Review 74, 315–330. https://doi.org/10.3828/tpr.74.3.4

Buitelaar, E., Segeren, A., 2011. Urban Structures and Land. The Morphological Effects of Dealing with Property Rights. Housing Studies 26, 661–679. https://doi.org/10.1080/02673037.2011.581909

Caniggia, G., Maffei, G., 2001. Architectural Composition and Building Typology: Interpreting Basic Building. Alinea Editrice, Firenze.

Cantarino, J., Netto, V.M., 2017. Urban diversity and transformation: public housing and the "hidden morphology of plots," in: 11th Space Syntax Symposium. Lisbon, pp. 1–53.

Cataldi, G., Maffei, G.L., Vaccaro, P., 2002. Saverio Muratori and the Italian school of planning typology. Urban Morphology 6, 2–14.

Chau, K.W., Choy, L.H.T., Webster, C.J., 2018. Institutional innovations in land development and planning in the 20th and 21st centuries. Habitat International 75, 90–95. https://doi.org/10.1016/j.habitatint.2018.03.011

Chen, F., 2012. Interpreting urban micromorphology in China: case studies from Suzhou. Urban Morphology 16, 133–48.

Choay, F., 2017. L'urbanisme, utopies et réalités: une anthologie.

Chung, L.L.W., 1994. The economics of land-use zoning: a literature review and analysis of the work of Coase. Town Planning Review 65, 77. https://doi.org/10.3828/tpr.65.1.j15rh7037v511127

Colwell, P.F., Scheu, T., 1989. Optimal Lot size and Configuration. Journal of Urban Economics 26, 90–109.

Conzen, M., 1960. Alnwick, Northumberland: a study in town-plan analysis. Institute of British Geographers, London.

Conzen, M.P., 2009. How cities internalize their former urban fringes: a cross-cultural comparison. Urban Morphology 13, 29–54.

Cozzolino, S., 2019. The (anti) adaptive neighbourhoods. Embracing complexity and distribution of design control in the ordinary built environment. Environment and Planning B: Urban Analytics and City Science 239980831985745. https://doi.org/10.1177/2399808319857451

D'Acci, L. (Ed.), 2019. The Mathematics of Urban Morphology, Modeling and Simulation in Science, Engineering and Technology. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-030-12381-9

Dark, S.J., Bram, D., 2007. The modifiable areal unit problem (MAUP) in physical geography. Progress in Physical Geography: Earth and Environment 31, 471–479.

Demetriou, D., See, L., Stillwell, J., 2013a. A Parcel Shape Index for Use in Land Consolidation Planning.

Demetriou, D., Stillwell, J., See, L., 2013b. A GIS-based shape index for land parcels, in: First International Conference on Remote Sensing and Geoinformation of the Environment. Paphos, Cyprus.

Dovey, K., Pike, L., Woodcock, I., 2017. Incremental Urban Intensification: Transit-oriented Re-development of Small-lot Corridors. Urban Policy and Research 35, 261–274.

Dovey, K., Wood, S., 2015. Public/private urban interfaces: type, adaptation, assemblage. Journal of Urbanism: International Research on Placemaking and Urban Sustainability 8, 1–16.

Ersland, G., 2010. Plot longevity and urban land tenure: a Norwegian case study. Urban Morphology 14, 21–29.

Feliciotti, A., Romice, O., Porta, S., 2017. Urban regeneration, masterplans and resilience: the case of Gorbals. Glasgow. Urban Morphology 21, 61–79.

Feliciotti, A., Romice, O., Porta, S., 2016. Design for change: five proxies for resilience in the urban form. Open House International 41, 23–30.

Fialkowski, M., Bitner, A., 2008. Universal rules for fragmentation of land by humans. Landscape Ecology 23, 1013–1022.

Fusco, G., Araldi, A., 2017. The nine forms of the French Riviera: classifying urban fabrics from the pedestrian perspective, in: XXIV International Seminar of Urban Form. Valencia.

Gao, X., Asami, Y., 2007. Influence of lot size and shape on redevelopment projects. Land Use Policy 24, 212–222.

Gauthier, P., Gilliland, J., 2006. Mapping urban morphology: a classification scheme for interpreting contributions to the study of urban form. Urban Morphology 10, 41–50.

Gehl, J., 2010. Cities for people. Island Press, Washington.

Gibb, K., Nygaard, C., 2006. Transfers, Contracts and Regulation: A New Institutional Economics Perspective on the Changing Provision of Social Housing in Britain. Housing Studies 21, 825–850. https://doi.org/10.1080/02673030600917719

Gil, J., Beirao, J., Montenegro, N., Duarte, J., 2012. On the discovery of urban typologies: data mining the many dimensions of urban form. Urban 16, 27–40.

Harvey, D., 1969. Explanation in Geography. Edward Arnold, London.

Hausleitner, B., 2017. Development of a configurational typology for micro-businesses integrating geometric and configurational variables, in: Proceedings of the 11th Space Syntax Symposium. Lisbon.

Hillier, B., 1996. Space is the machine: a configurational theory of architecture. Cambridge Univ. Press, Cambridge.

Hillier, B., Hanson, J., 1984. Social Logic of Space. Cambridge University Press, Cambridge.

Hillier, B., Iida, S., 2005. Network and Psychological Effects in Urban Movement, in: Cohn, A.G., Mark, D.M. (Eds.), Spatial Information Theory. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 475–490. https://doi.org/10.1007/11556114_30

Hillier, B., Penn, A., Hanson, J., Grajewski, T., Xu, J., 1993. Natural movement: or, configuration and attraction in urban pedestrian movement. Environment and Planning B 20, 29–66.

Hopkins, M., 2012. The ecological significance of urban fringe belts. Urban Morphology 16, 41–54.

Jacobs, J., 1961. The Death and Life of Great American Cities. Random House, New York.

Kim, D., 2009. On the Silhouette Plot in Cluster Analysis. Journal of the Korean Data Analysis Society 11, 2955–2963.

Kim, D., Lucinda, P., Ian, W., 2017. Incremental Urban Intensification: Transitoriented Re-development of Small-lot Corridors. Urban Policy and Research 35, 261–274.

Kropf, K., 2019. Plots, formalism and the limits of the minimal. Urban Morphology 23, 2–4.

Kropf, K., 2018. Plots, property and behaviour. Urban Morphol. 22, 1–10.

Kropf, K., 2017. The handbook of urban morphology, The urban handbook series. Wiley, Chichester.

Kropf, K., 2009. Aspects of urban form. Urban Morphology 13, 105–120.

Kropf, K., 1997. When is a plot not a plot: problems in representation and interpretation. unpublished paper presented to the Fourth International Seminar on Urban Form. University of Birmingham, Birmingham.

Kropf, K., 1996. Urban tissue and the character of towns. Urban design. international 1.

Lai, L.W.C., Davies, S.N.G., 2017. A Coasian boundary inquiry on zoning and property rights: Lot and zone boundaries and transaction costs. Progress in Planning 118, 1–28. https://doi.org/10.1016/j.progress.2016.05.001

Lai, L.W.C., Davies, S.N.G., Chau, K.W., Ching, K.S.T., Chua, M.H., Leung, H.F., Lorne, F.T., 2018. The determination of the "true" property boundary in planned development: a Coasian analysis. The Annals of Regional Science 61, 579–599. https://doi.org/10.1007/s00168-018-0871-8

Lai, L.W.C., Hung, C.W.Y., 2008. The Inner Logic of the Coase Theorem and a Coasian Planning Research Agenda. Environment and Planning B: Planning and Design 35, 207–226. https://doi.org/10.1068/b33057

Lefebvre, H., Kofman, E., Lebas, E., 1996. Writings on cities. Blackwell Publishers, Cambridge, Mass, USA.

Levy, A., 1999. Urban morphology and the problem of the modern urban fabric: some questions for research. Urban Morphology 3, 79–85.

Love, T., Crawford, C., 2011. Plot logic: character-building through creative parcelisation, in: Tiesdall, S., Adams, D. (Eds.), Urban Design in the Real Estate Developments Process. West Sussex: Wiley-Blackwell, pp. 92–113.

Maniruzzaman, K., Asami, Y., Okabe, A., 1994. Land use and geometry of lots in Setagaya Ward, Tokyo. Theory and Applications of GIS 2, 83–90. https://doi.org/10.5638/thagis.2.83

Marcus, L., 2010. Spatial Capital. 'A proposal for an Extension of Space Syntax into a More General Urban Morphology.' The Journal of Space Syntax 1, 30–40.

Marcus, L., 2001. The impact of land-division on long-term occupation – the possibility of such a thing as 'natural occupation,' in: Third International Space Syntax Symposium. Tech, Atlanta: Georgia.

Marcus, L., 2000. Architectural knowledge and urban form. The functional performance of architectural urbanity. KTH Royal Institute of Technology in Stockholm.

Marcus, L., Bergauser Pont, M., Bobkova, E., 2017. Cities as Accessible Densities and Diversities: Adding attraction variables to configurational analysis, in: 11th International Space Syntax Symposium. Instituto Superior Técnico, Lisbon.

Marcus, L., Bobkova, E., 2019. Spatial configuration of plot systems and urban diversity: empirical support for a differentiation variable in spatial morphology, in: The 12th Space Syntax Symposium. Beijing.

Marshall, S., 2005. Streets and patterns: the structure of urban geometry. Spon, London.

Merill, T.W., 1998. Property and the Right to Exclude. Nebraska Law Review 77.

Moroni, S., Rauws, W., Cozzolino, S., 2019. Forms of self-organization: Urban complexity and planning implications. Environment and Planning B: Urban Analytics and City Science 239980831985772. https://doi.org/10.1177/2399808319857721

Moudon, A., 1997. Urban morphology as an emerging interdisciplinary field. Urban 1, 3–10.

Moudon, A.V., 1994. Getting to know the built landscape: typomorphology, in: Schneekloth, K.A. (Ed.), Ordering Space: Types in Architecture and Design. Van Nostrand Reinhold, New York, pp. 289–311.

Moudon, A.V., 1992. A catholic approach to organising what urban designers should know. Journal of Planning Literature 6, 331–349.

Moudon, A.V., 1986. Built for change: neighborhood architecture in San Francisco. MIT Press, Cambridge, Mass.

Needham, B., 2006. Planning law and economics: an investigation of the rules we make for using land, RTPI library series. Routledge, Milton Park, Abingdon, Oxon ; New York, NY.

Oliveira, V., 2016. Urban morphology: an introduction to the study of the physical form of cities, The Urban Book Series. Springer, Switzerland.

Oliveira, V., 2013. Morpho: a methodology for assessing urban form. Urban Morphology 17, 21–33.

Oliveira, V., Medeiros, V., 2016. Morpho: Combining morphological measures. Environment and Planning. B 43, 805–825.

Oliveira, V., Monteiro, C., Partanen, J., 2015. A comparative study of urban form'. Urban Morphology 19, 73–92.

Openshaw, S., Taylor, P., 1979. A million or so correlation coefficients: three experiments on the modifiable areal unit problem, in: Wrigley, N. (Ed.), Statistical Applications in Spatial Sciences. Pion, London, pp. 127–144.

Osaragi, T., 2014. Stochastic models describing subdivision of building lots. Procedia Environmental Sciences 22, 352–365.

O'Sullivan, A., 2019. Urban economics, Ninth edition. ed. McGraw-Hill Education, New York, NY.

Paasch, J.M., 2011. Classification of real property rights - A comparative study of real property rights in Germany, Ireland, the Netherlands and Sweden. KTH Royal Institute of Technology, Stockholm, Sweden.

Panerai, P. (Ed.), 2004. Urban forms: death and life of the urban block. Architectural Press, Oxford.

Quatremère de Quincy, Younés, S., 1999. The true, the fictive, and the real: the historical dictionary of architecture of Quatremere de Quincy. A. Papadakis, London.

Sayyar, S.S., Marcus, L., 2013. Designing difference: interpreting and testing Jane Jacobs' criteria for urban diversity in space syntax terms, in: Proceedings of the 9th Space Syntax Symposium. Seoul: Sejong University, p. 2.

Scheer, B., 2018. Towards a minimalist definition of the plot. Viewpoint. Urban Morphology 22, 162–163.

Scheer, B.C., 2017. The evolution of urban form. Typology for planners and architects. London and. Routledge, New York.

Scheer, B.C., 2016. The epistemology of urban morphology. Urban Morphology 20, 5–17.

Scheer, B.C., 2001. The Anatomy of Sprawl. Places 14, 28–37.

Scoppa, M.D., Peponis, J., 2015. Distributed attraction: the effects of street network connectivity upon the distribution of retail frontage in the City of Buenos Aires. Environment and Planning B 42, 354–378.

Serra, M., 2013. Anatomy of Emerging Metropolitan Territory: Towards an Integrated Analytical Framework for Metropolitan Morphology. Universidade do Porto, Porto.

Serra, M., Pinho, P., 2013. Tackling the structure of very large spatial systems - Space syntax and the analysis of metropolitan form. The Journal of Space Syntax 4, 179–196.

Sevstuk, A., Kalvo, R., Ekmekci, O., 2016. Pedestrian accessibility in grid layouts: the role of block, plot and street dimensions. Urban Morphology 20, 89–106.

Siksna, A., 1998. City centre blocks and their evolution: a comparative study of eight American and Australian CBDs. Journal of Urban Design 3, 253–283.

Slater, T., 1981. The analysis of burgage patterns in medieval towns. Area 13, 211–216.

Souza, F.D., Ochi, T., Hosono, A., 2018. Land Readjustment: Solving Urban Problems Through Innovative Approach. Japan, Tokyo.

Ståhle, A., 2008. Compact sprawl: exploring public open space and contradictions in urban density. PhD Dissertation. KTH University, Stockholm.

Steadman, P., 2014. Density and Built Form: Integrating 'Spacemate' with the Work of Martin and March. Environment and Planning B: Planning and Design 41, 341–358. https://doi.org/10.1068/b39141

Steadman, P., 1983. Architectural morphology: an introduction to the geometry of building plans. Pion, London.

Talen, E., 2008. Design for diversity. Exploring socially mixed neighbourhoods. Elsevier Ltd, Oxford, UK.

Tarbatt, J., 2012. The Plot: Designing Diversity in the Built Environment: A Manual for Architects and Urban Designers. RIBA Publications, London.

UN Habitat, 2014. A new strategy of sustainable neighbourhood planning: five principles (Discussion note 3).

Ünlü, T., Baş, Y., 2017. Morphological processes and the making of residential forms: morphogenetic types in Turkish cities. Urban Morphology 21, 105–122.

Usui, H., 2018. Statistical distribution of building lot frontage: application for Tokyo downtown districts. Journal of Geographical Systems 20, 295–316.

Vialard, A., 2013. A typology of block-faces. PhD Deissertation. Georgia Institute of Technology, Georgia.

Vialard, A., 2012. Measures of the fit between street network, urban blocks and building footprints, in: Eighth International Space Syntax Symposium. pp. 8101:1 – 8101:17.

Vialard, A., Carpenter, A., 2015. Building density of parcels and block-faces from a syntactical, morphological and planning perspective, in: Proceedings of the 10th International Space Syntax Symposium. Presented at the the 10th International Space Syntax Symposium, UCL, London, pp. 100:1-100:17.

Webster, C., Lai, L.W.-C., 2003. Property Rights, Planning and Markets. Managing Spontaneous Cities. Edward Edgar Publishing Limited, Cheltenham, UK.

Whitehand, J., 2001. Changing suburban landscapes at the microscale. Tijdschrift voor Economische en Sociale. Geografie 92, 164–184.

Whitehand, J.W.R., 2001. British urban morphology: the Conzenian tradition. Urban Morphology 5, 103–109.

Whitehand, J.W.R., Gu, K., Conzen, M.P., Whitehand, S.M., 2014. The Typological Process and the Morphological Period: A Cross-Cultural Assessment. Environment and Planning B: Planning and Design 41, 512–533. https://doi.org/10.1068/b39097

Wilson, A.G., 2000. Complex spatial systems: the modelling foundations of urban and regional analysis. Prentice Hall, Harlow.

Zeka, E., Yuzer, M.A., 2019. A methodology for measuring the form of organic settlements. MethodsX 6, 368–376. https://doi.org/10.1016/j.mex.2019.02.009

Zhang, J., 2015. Urban morphological processes in China: a Conzenian approach. Urban Morphology 19, 35–56.

Zhang, L., Ding, W., 2018. Changing urban form in a planned economy: the case of Nanjing. Urban Morphology 22, 15–34.

Zhu, J., Sim, L.-L., Liu, X., 2007. Place Remaking under Property Rights Regimes: A Case Study of Niucheshui, Singapore. Environment and Planning A: Economy and Space 39, 2346–2365. https://doi.org/10.1068/a38333